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Jirapong et al.

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(54) **SYSTEM AND METHOD FOR MITIGATING AN OCCURRENCE OF A DRY SPOT IN A FIELD OF VIEW OF A STAR TRACKER**

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(51) **Int. Cl.**

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B64G 1/24	(2006.01)
G01C 21/02	(2006.01)
G06F 17/30	(2006.01)
B64G 1/36	(2006.01)

(52) **U.S. Cl.**

CPC ***G01C 21/025*** (2013.01); ***B64G 1/361*** (2013.01); ***G01C 25/00*** (2013.01); ***G06F 17/30241*** (2013.01); *B64G 2001/245* (2013.01)

(58) **Field of Classification Search**

CPC B64G 1/361; B64G 1/286; B64G 1/24; G01S 3/7867; G01C 25/00; G05D 1/0883

USPC 701/13, 513, 4; 73/862.041; 348/144; 244/171; 250/203.1, 206.1

See application file for complete search history.

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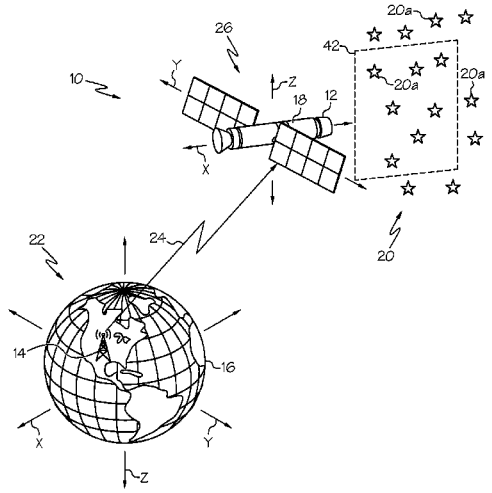
(57) **ABSTRACT**

A system and method for mitigating an occurrence of a dry spot, the method may include: (1) predicting the occurrence of the dry spot by at least one of determining a location of the occurrence of the dry spot, determining a date of the occurrence of the dry spot, and determining a duration of the occurrence of the dry spot; (2) generating a visualization of the occurrence of the dry spot, and (3) modifying a star catalog to reduce an impact of the dry spot by at least one of generating a set of modification to modify the star catalog, generating a modification schedule for modifying the star catalog, and uploading the set of modifications to the star catalog.

24 Claims, 13 Drawing Sheets



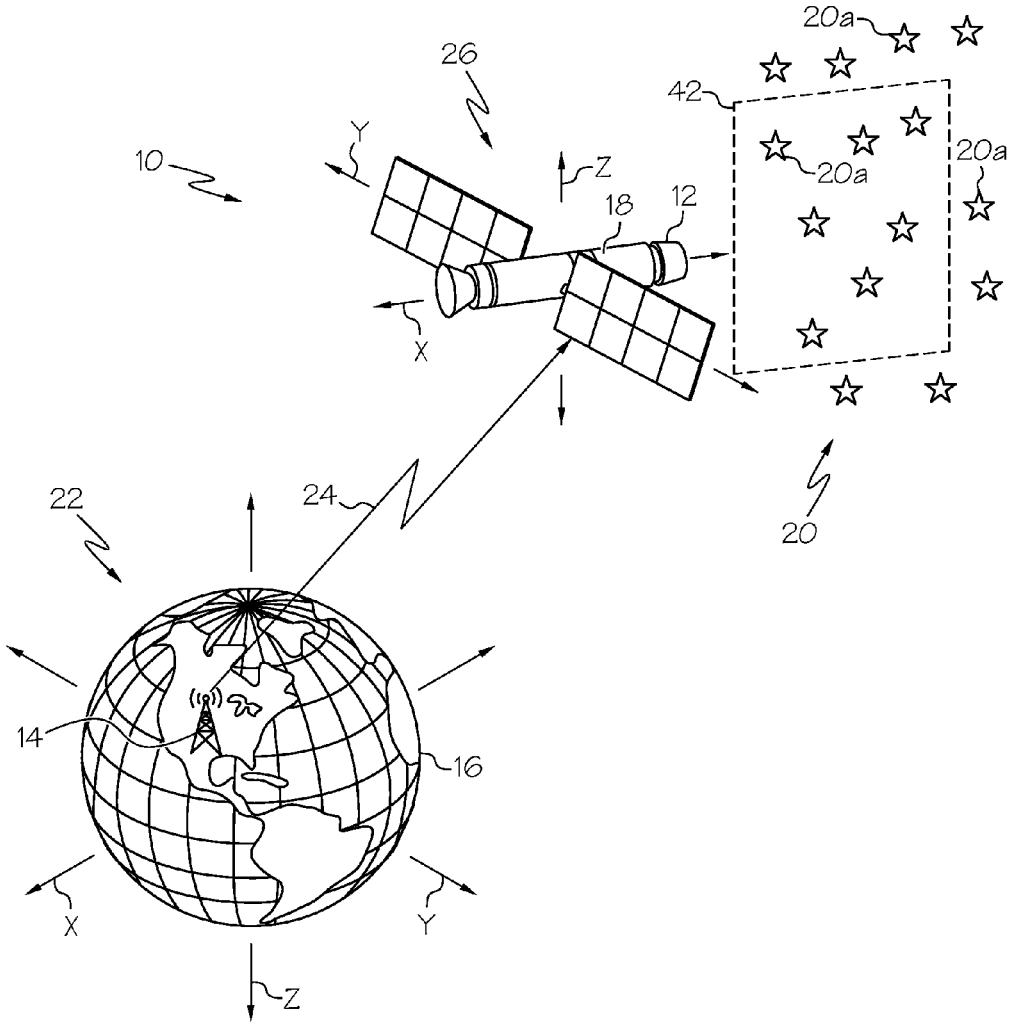


FIG. 1

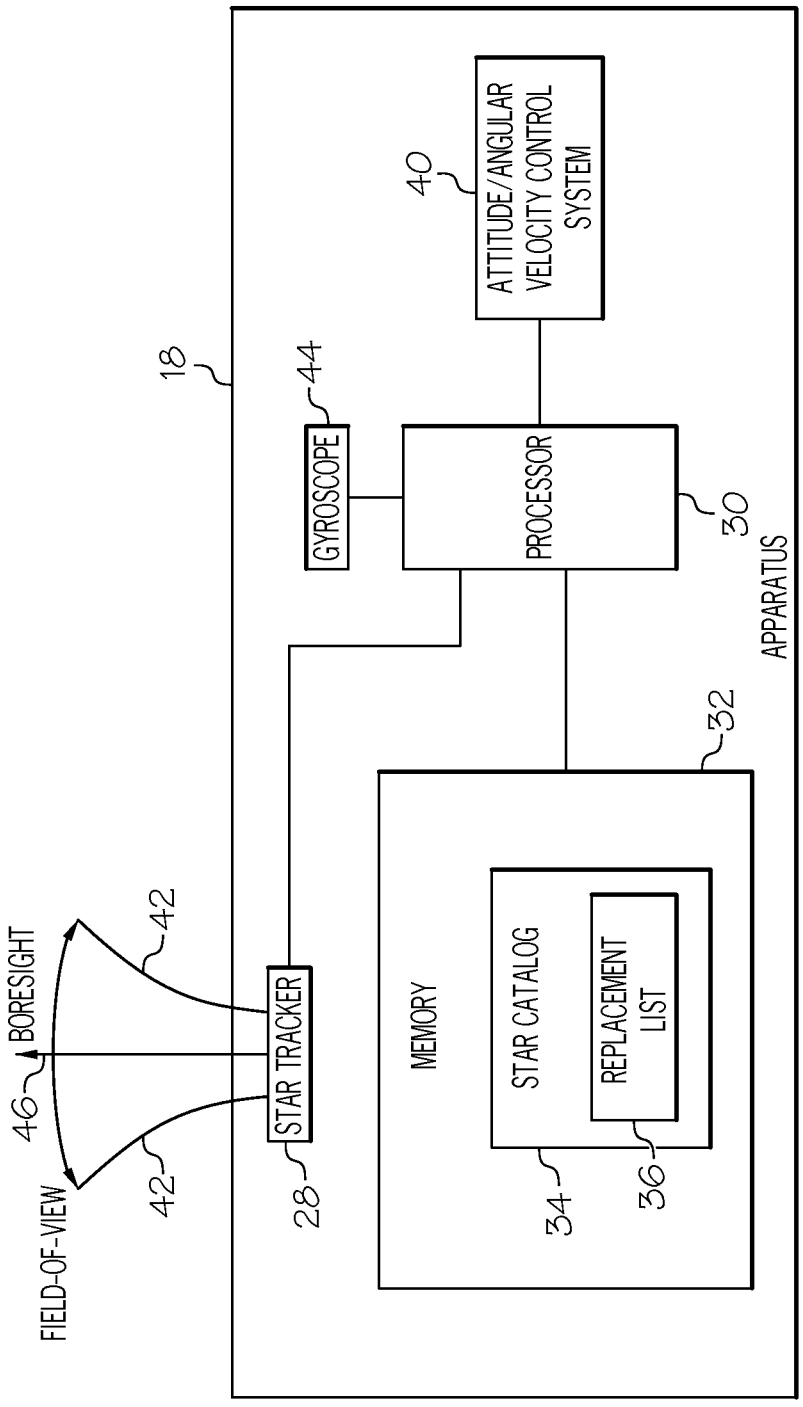

18
40
ATTITUDE/ANGULAR VELOCITY CONTROL SYSTEM
44
GYROSCOPE
PROCESSOR
30
APPARATUS
32
MEMORY
STAR CATALOG
REPLACEMENT LIST
34
36
28
STAR TRACKER
42
42
BORESIGHT
46
FIELD-OF-VIEW

FIG. 2

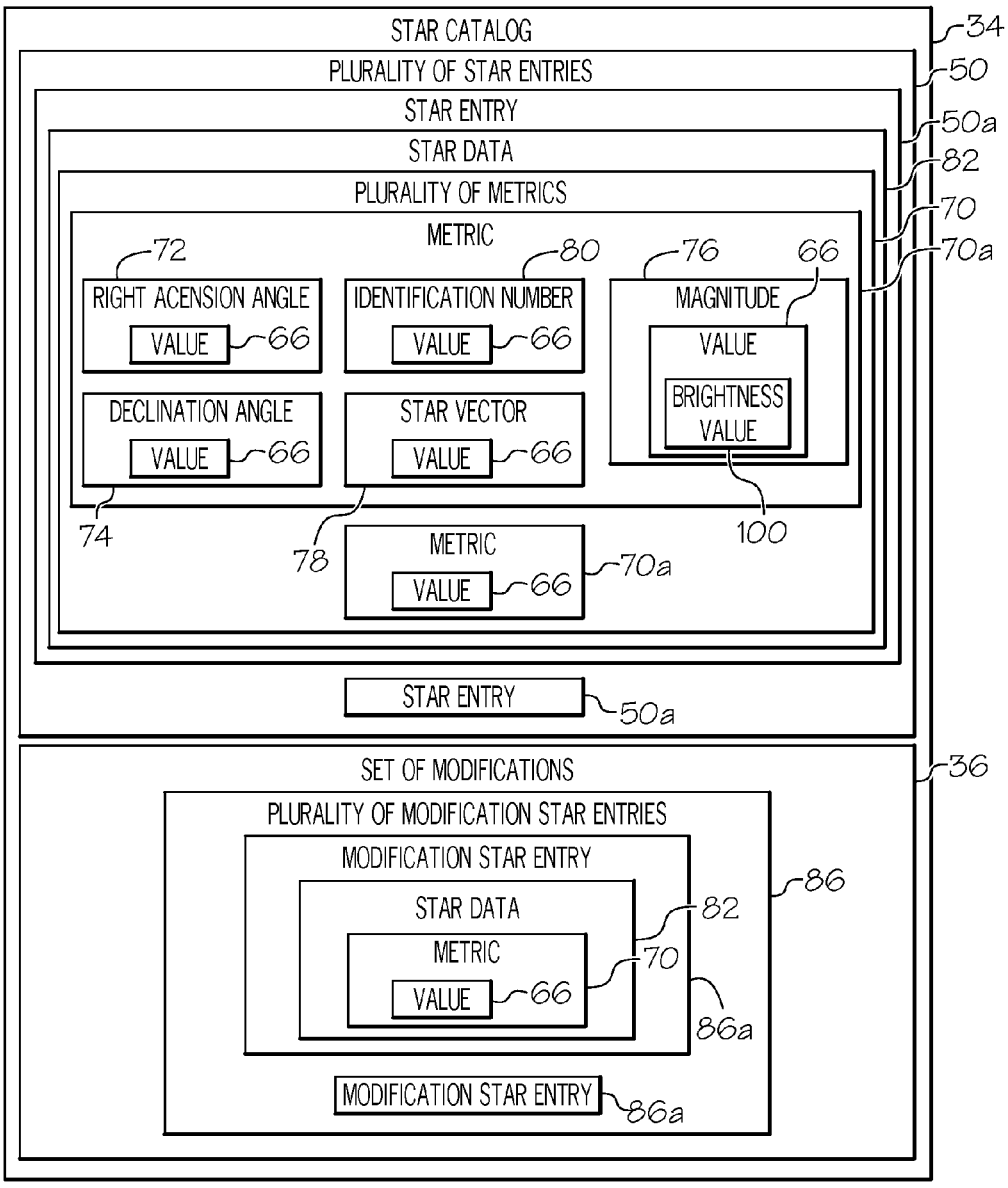

STAR CATALOG
34
PLURALITY OF STAR ENTRIES
50
STAR ENTRY
50a
STAR DATA
82
PLURALITY OF METRICS
70
METRIC
70a
72
80
76
66
RIGHT ACENSION ANGLE
VALUE
66
IDENTIFICATION NUMBER
VALUE
66
MAGNITUDE
VALUE
BRIGHTNESS VALUE
DECLINATION ANGLE
VALUE
66
STAR VECTOR
VALUE
66
74
78
100
METRIC
VALUE
66
70a
STAR ENTRY
50a
SET OF MODIFICATIONS
36
PLURALITY OF MODIFICATION STAR ENTRIES
MODIFICATION STAR ENTRY
86
STAR DATA
82
METRIC
70
VALUE
66
86a
MODIFICATION STAR ENTRY
86a

FIG. 3

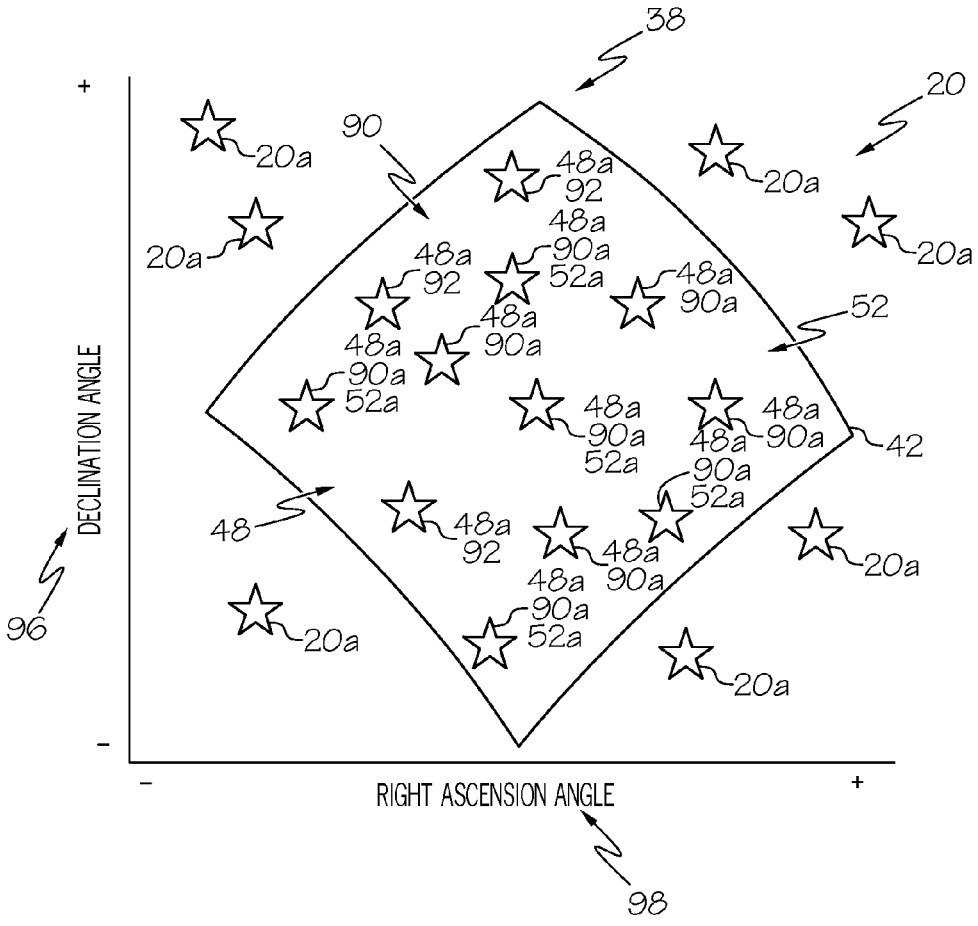

38
20
90
20a
48a
92
90a
52a
52
42
48
96
98
DECLINATION ANGLE
RIGHT ASCENSION ANGLE
+
-

FIG. 4

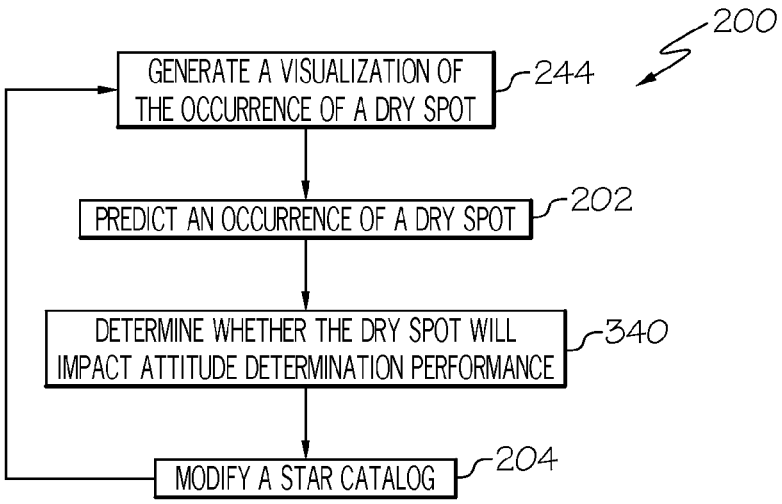

200
GENERATE A VISUALIZATION OF THE OCCURRENCE OF A DRY SPOT
244
PREDICT AN OCCURRENCE OF A DRY SPOT
202
DETERMINE WHETHER THE DRY SPOT WILL IMPACT ATTITUDE DETERMINATION PERFORMANCE
340
MODIFY A STAR CATALOG
204

FIG. 5

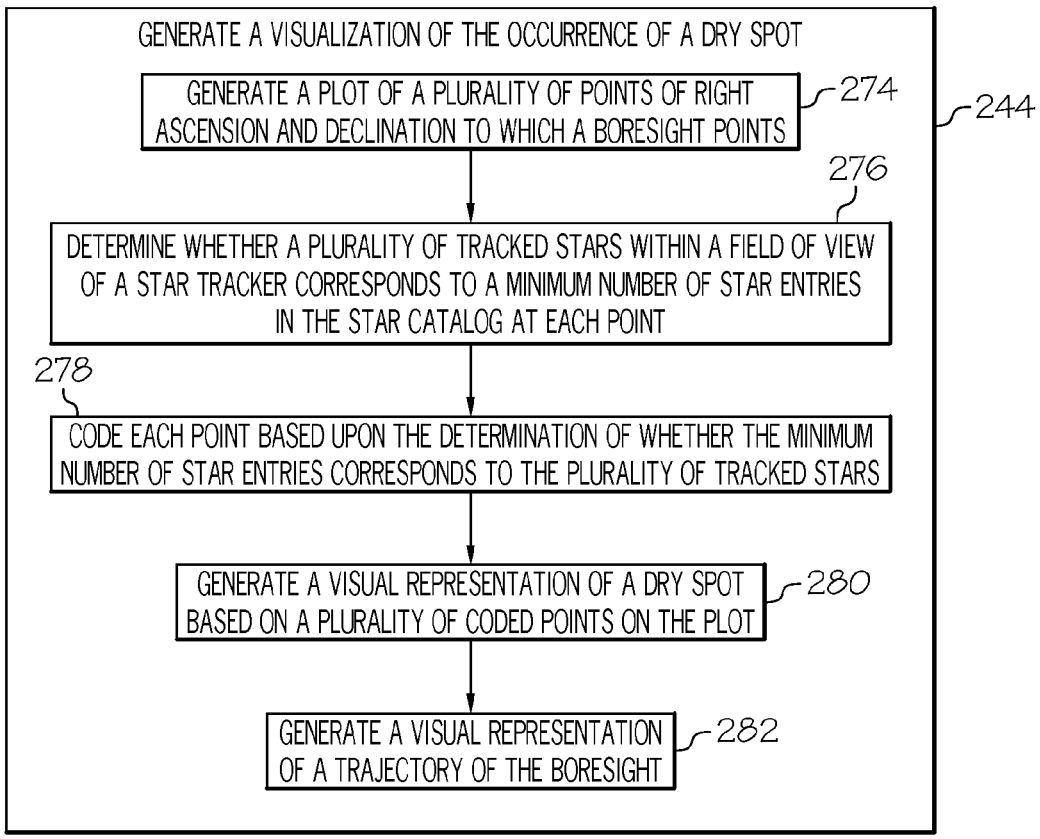

GENERATE A VISUALIZATION OF THE OCCURRENCE OF A DRY SPOT
244
GENERATE A PLOT OF A PLURALITY OF POINTS OF RIGHT ASCENSION AND DECLINATION TO WHICH A BORESIGHT POINTS
274
276
DETERMINE WHETHER A PLURALITY OF TRACKED STARS WITHIN A FIELD OF VIEW OF A STAR TRACKER CORRESPONDS TO A MINIMUM NUMBER OF STAR ENTRIES IN THE STAR CATALOG AT EACH POINT
278
CODE EACH POINT BASED UPON THE DETERMINATION OF WHETHER THE MINIMUM NUMBER OF STAR ENTRIES CORRESPONDS TO THE PLURALITY OF TRACKED STARS
GENERATE A VISUAL REPRESENTATION OF A DRY SPOT BASED ON A PLURALITY OF CODED POINTS ON THE PLOT
280
GENERATE A VISUAL REPRESENTATION OF A TRAJECTORY OF THE BORESIGHT
282

FIG. 6

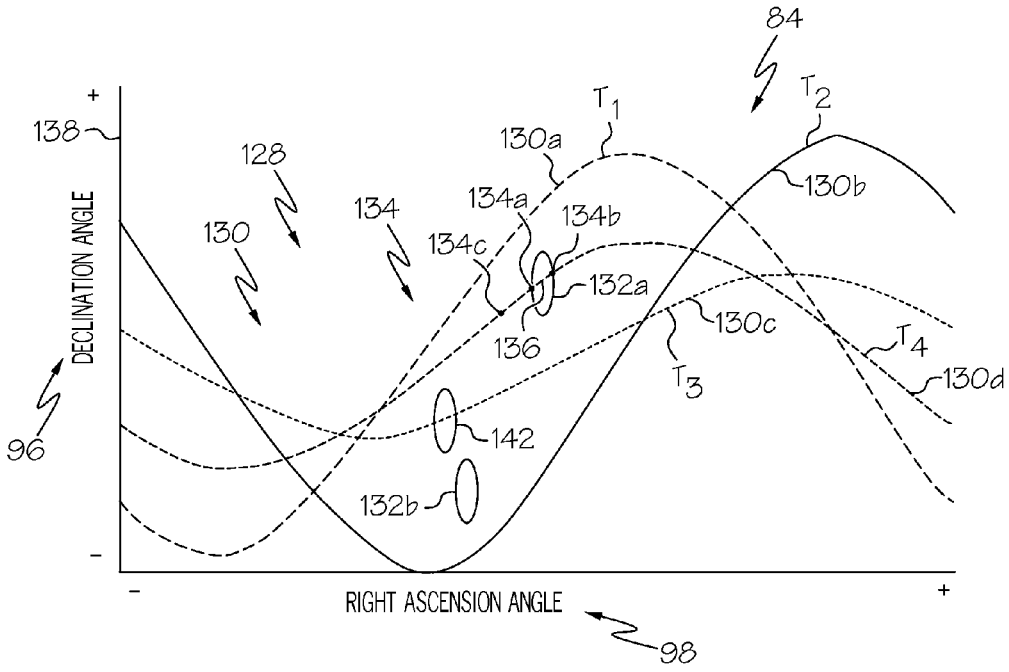

84
T1
T2
+
138
128
130a
130b
134
134a
134b
130
134c
132a
DECLINATION ANGLE
130c
136
T4
T3
130d
96
142
132b
-
-
RIGHT ASCENSION ANGLE
+
98

FIG. 7

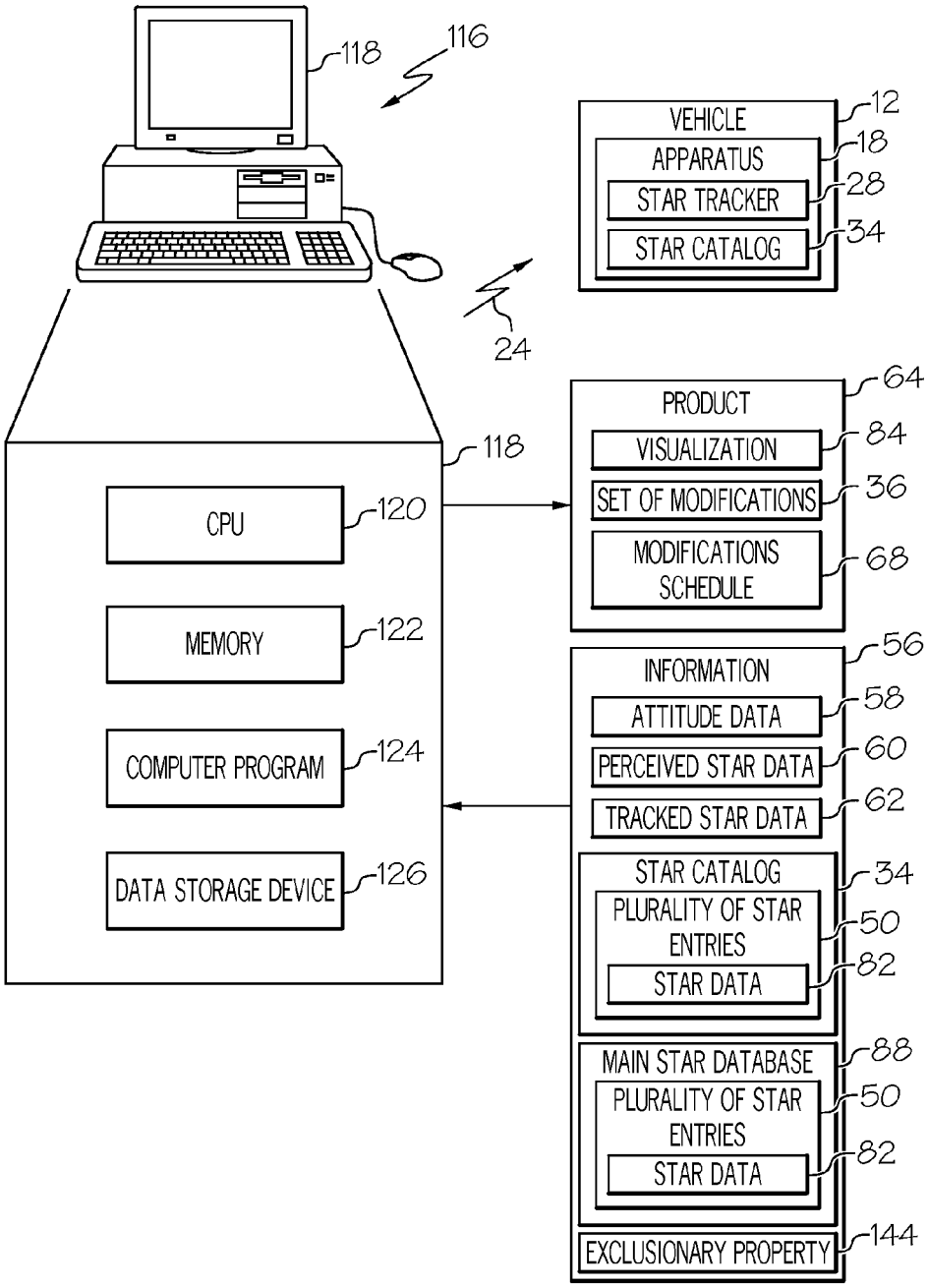

118
116
VEHICLE
12
APPARATUS
18
STAR TRACKER
28
STAR CATALOG
34
24
64
PRODUCT
118
VISUALIZATION
84
SET OF MODIFICATIONS
36
CPU
120
MODIFICATIONS SCHEDULE
68
MEMORY
122
56
INFORMATION
ATTITUDE DATA
58
COMPUTER PROGRAM
124
PERCEIVED STAR DATA
60
TRACKED STAR DATA
62
STAR CATALOG
34
DATA STORAGE DEVICE
126
PLURALITY OF STAR ENTRIES
50
STAR DATA
82
MAIN STAR DATABASE
88
PLURALITY OF STAR ENTRIES
50
STAR DATA
82
EXCLUSIONARY PROPERTY
144

FIG. 8

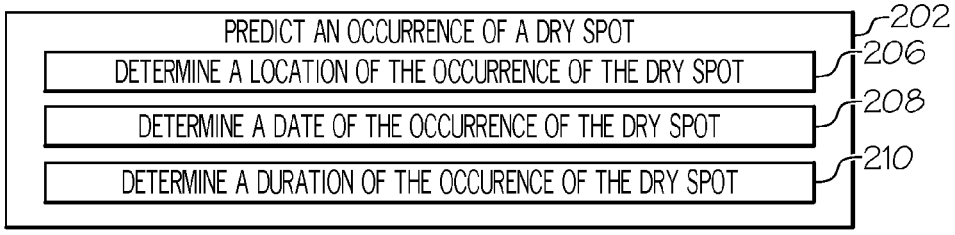


FIG. 9

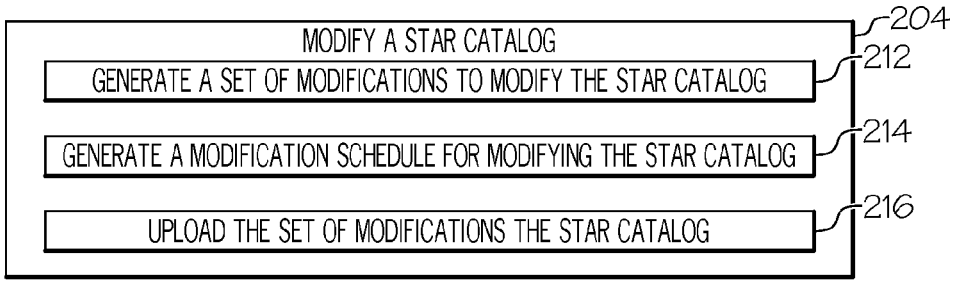


FIG. 10

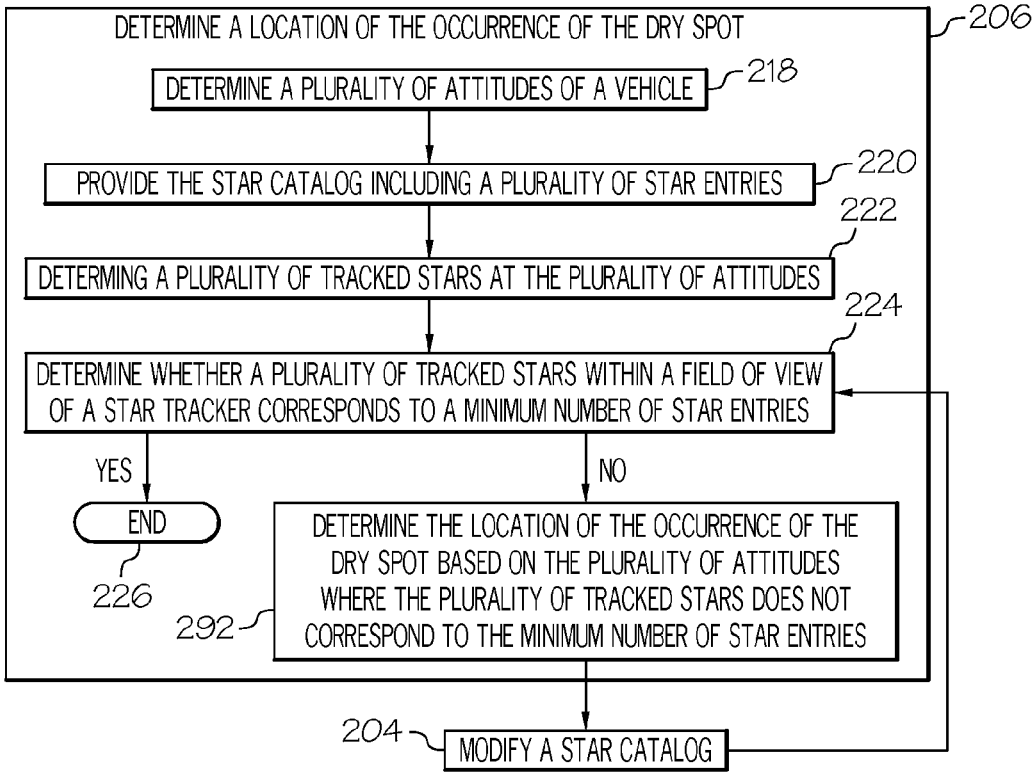


FIG. 11

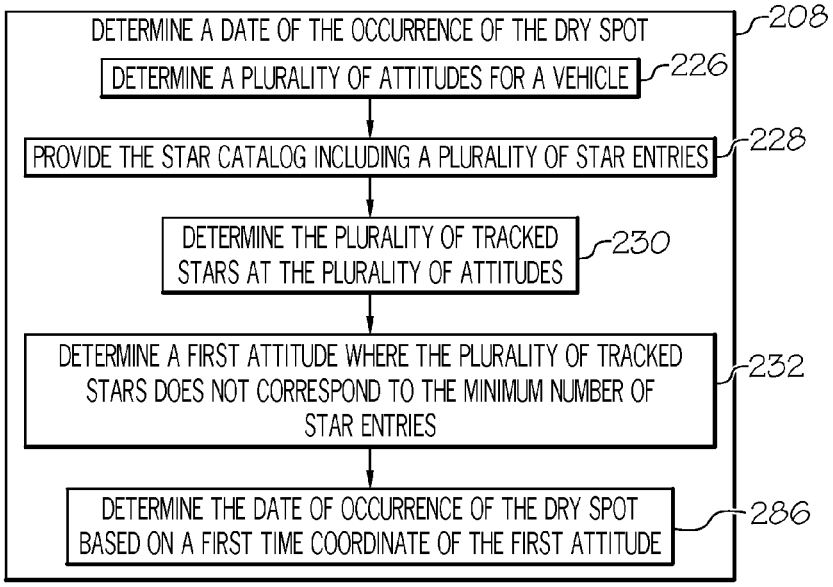

DETERMINE A DATE OF THE OCCURRENCE OF THE DRY SPOT
208
DETERMINE A PLURALITY OF ATTITUDES FOR A VEHICLE
226
PROVIDE THE STAR CATALOG INCLUDING A PLURALITY OF STAR ENTRIES
228
DETERMINE THE PLURALITY OF TRACKED STARS AT THE PLURALITY OF ATTITUDES
230
DETERMINE A FIRST ATTITUDE WHERE THE PLURALITY OF TRACKED STARS DOES NOT CORRESPOND TO THE MINIMUM NUMBER OF STAR ENTRIES
232
DETERMINE THE DATE OF OCCURRENCE OF THE DRY SPOT BASED ON A FIRST TIME COORDINATE OF THE FIRST ATTITUDE
286

FIG. 12

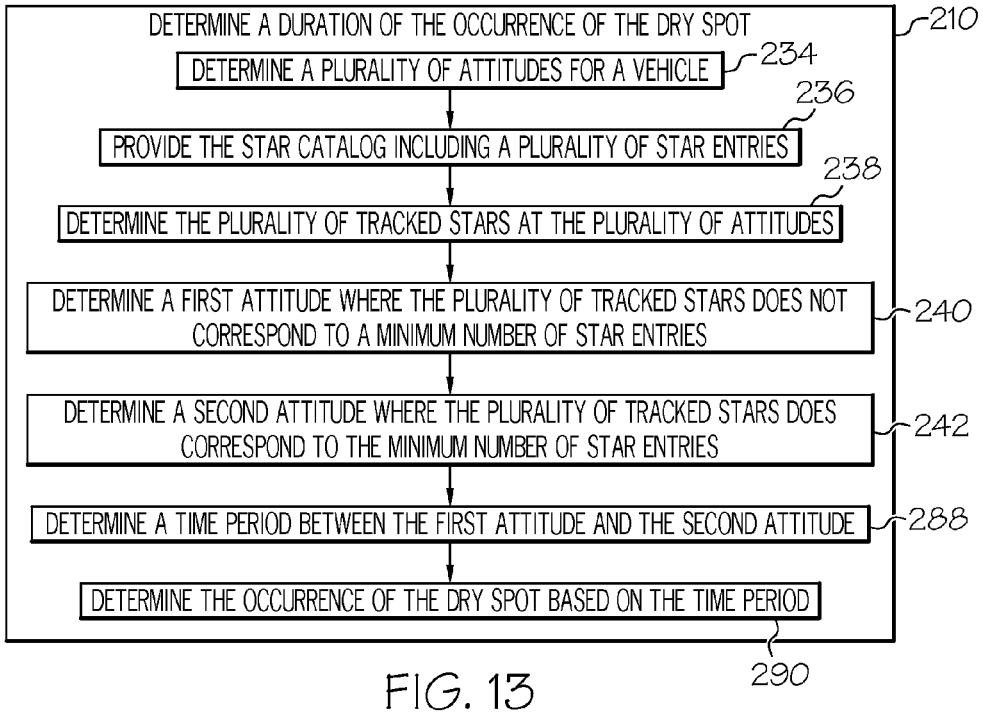

DETERMINE A DURATION OF THE OCCURRENCE OF THE DRY SPOT
210
DETERMINE A PLURALITY OF ATTITUDES FOR A VEHICLE
234
PROVIDE THE STAR CATALOG INCLUDING A PLURALITY OF STAR ENTRIES
236
DETERMINE THE PLURALITY OF TRACKED STARS AT THE PLURALITY OF ATTITUDES
238
DETERMINE A FIRST ATTITUDE WHERE THE PLURALITY OF TRACKED STARS DOES NOT CORRESPOND TO A MINIMUM NUMBER OF STAR ENTRIES
240
DETERMINE A SECOND ATTITUDE WHERE THE PLURALITY OF TRACKED STARS DOES CORRESPOND TO THE MINIMUM NUMBER OF STAR ENTRIES
242
DETERMINE A TIME PERIOD BETWEEN THE FIRST ATTITUDE AND THE SECOND ATTITUDE
288
DETERMINE THE OCCURRENCE OF THE DRY SPOT BASED ON THE TIME PERIOD
290

FIG. 13

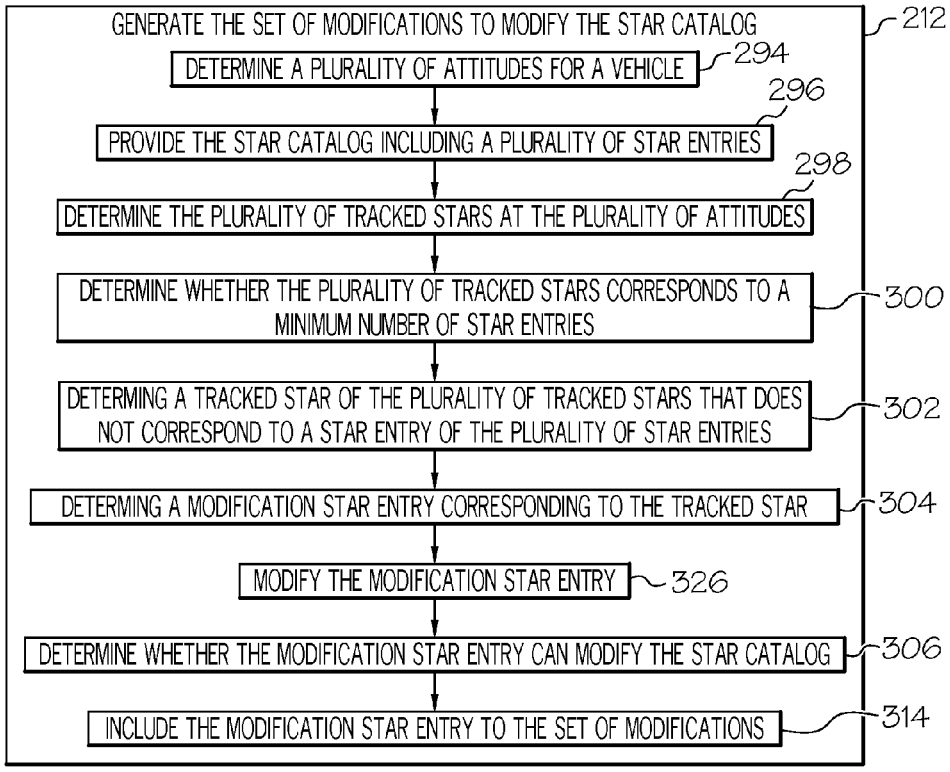

GENERATE THE SET OF MODIFICATIONS TO MODIFY THE STAR CATALOG
212
DETERMINE A PLURALITY OF ATTITUDES FOR A VEHICLE
294
PROVIDE THE STAR CATALOG INCLUDING A PLURALITY OF STAR ENTRIES
296
DETERMINE THE PLURALITY OF TRACKED STARS AT THE PLURALITY OF ATTITUDES
298
DETERMINE WHETHER THE PLURALITY OF TRACKED STARS CORRESPONDS TO A MINIMUM NUMBER OF STAR ENTRIES
300
DETERMING A TRACKED STAR OF THE PLURALITY OF TRACKED STARS THAT DOES NOT CORRESPOND TO A STAR ENTRY OF THE PLURALITY OF STAR ENTRIES
302
DETERMING A MODIFICATION STAR ENTRY CORRESPONDING TO THE TRACKED STAR
304
MODIFY THE MODIFICATION STAR ENTRY
326
DETERMINE WHETHER THE MODIFICATION STAR ENTRY CAN MODIFY THE STAR CATALOG
306
INCLUDE THE MODIFICATION STAR ENTRY TO THE SET OF MODIFICATIONS
314

FIG. 14

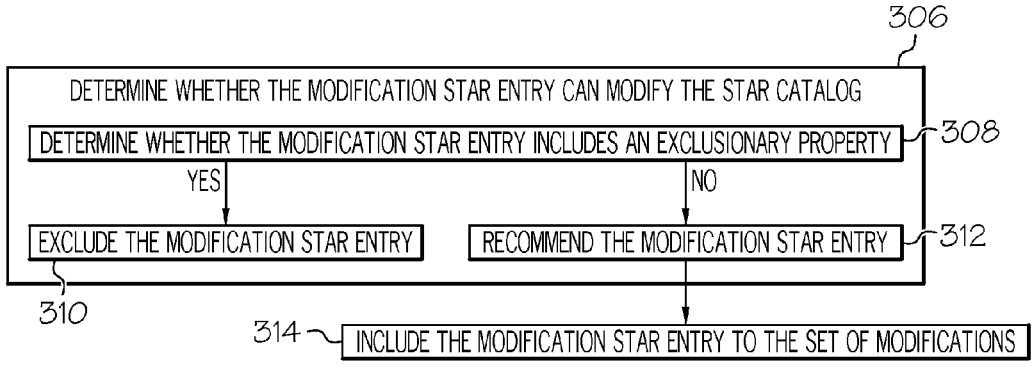

306
DETERMINE WHETHER THE MODIFICATION STAR ENTRY CAN MODIFY THE STAR CATALOG
DETERMINE WHETHER THE MODIFICATION STAR ENTRY INCLUDES AN EXCLUSIONARY PROPERTY
308
YES
NO
EXCLUDE THE MODIFICATION STAR ENTRY
RECOMMEND THE MODIFICATION STAR ENTRY
312
310
314
INCLUDE THE MODIFICATION STAR ENTRY TO THE SET OF MODIFICATIONS

FIG. 15

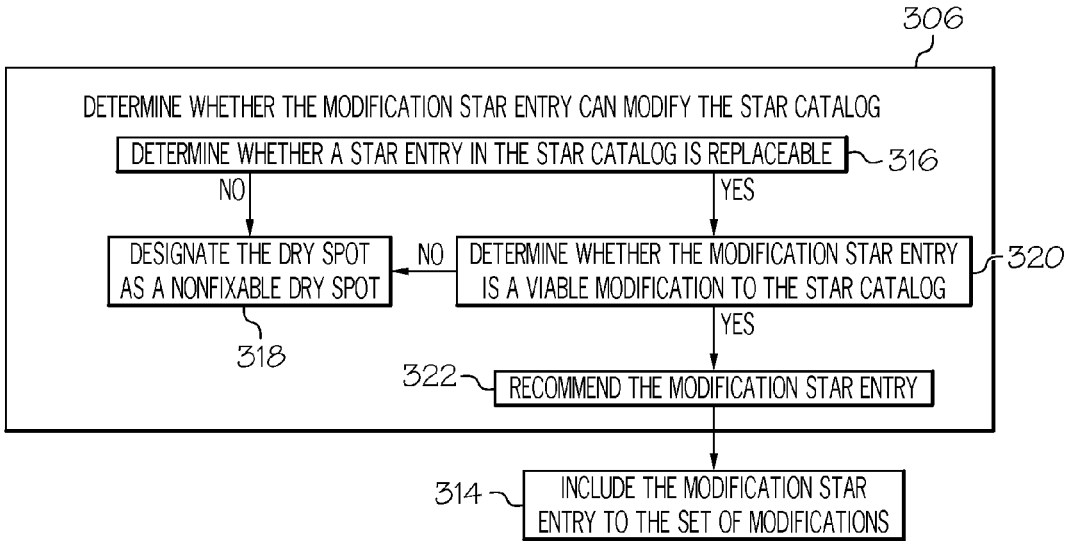

306
DETERMINE WHETHER THE MODIFICATION STAR ENTRY CAN MODIFY THE STAR CATALOG
DETERMINE WHETHER A STAR ENTRY IN THE STAR CATALOG IS REPLACEABLE
316
NO
YES
DESIGNATE THE DRY SPOT AS A NONFIXABLE DRY SPOT
NO
DETERMINE WHETHER THE MODIFICATION STAR ENTRY IS A VIABLE MODIFICATION TO THE STAR CATALOG
320
318
YES
322
RECOMMEND THE MODIFICATION STAR ENTRY
314
INCLUDE THE MODIFICATION STAR ENTRY TO THE SET OF MODIFICATIONS

FIG. 16

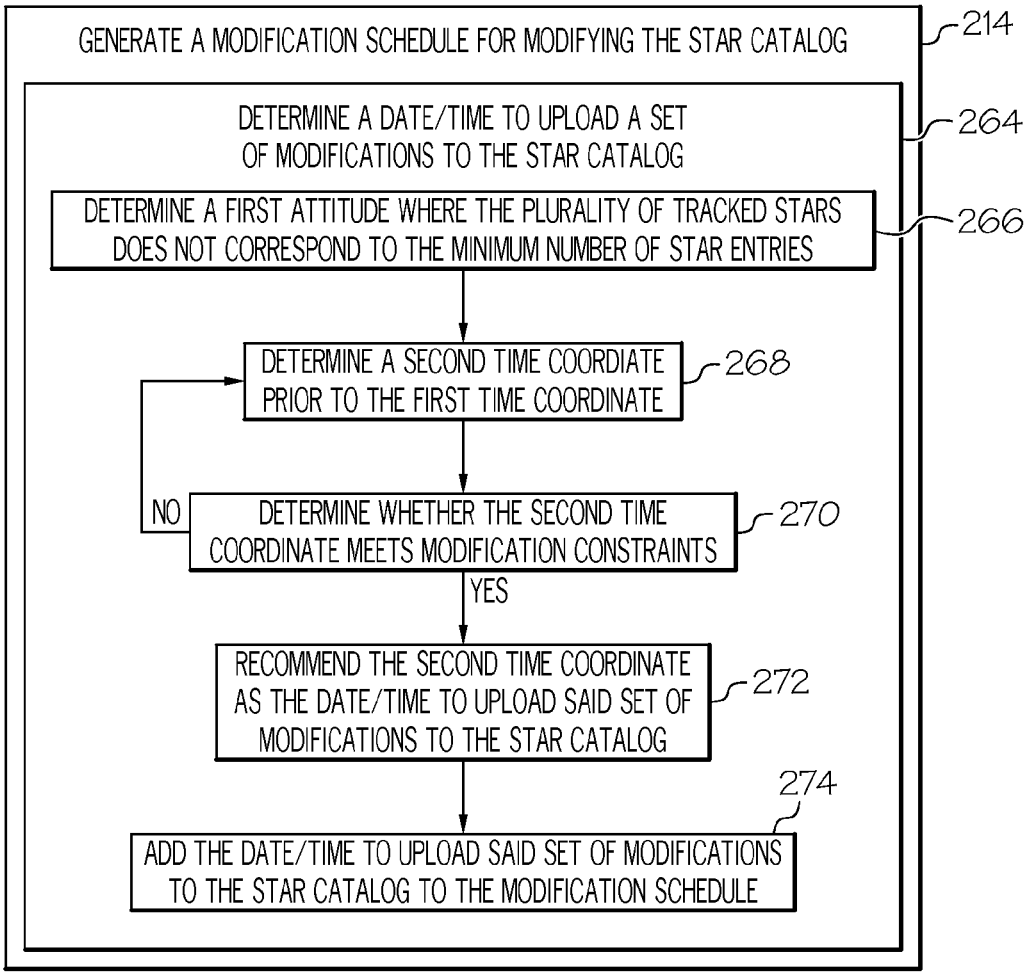

GENERATE A MODIFICATION SCHEDULE FOR MODIFYING THE STAR CATALOG
214
DETERMINE A DATE/TIME TO UPLOAD A SET OF MODIFICATIONS TO THE STAR CATALOG
264
DETERMINE A FIRST ATTITUDE WHERE THE PLURALITY OF TRACKED STARS DOES NOT CORRESPOND TO THE MINIMUM NUMBER OF STAR ENTRIES
266
DETERMINE A SECOND TIME COORDIATE PRIOR TO THE FIRST TIME COORDINATE
268
NO
DETERMINE WHETHER THE SECOND TIME COORDINATE MEETS MODIFICATION CONSTRAINTS
270
YES
RECOMMEND THE SECOND TIME COORDINATE AS THE DATE/TIME TO UPLOAD SAID SET OF MODIFICATIONS TO THE STAR CATALOG
272
274
ADD THE DATE/TIME TO UPLOAD SAID SET OF MODIFICATIONS TO THE STAR CATALOG TO THE MODIFICATION SCHEDULE

FIG. 17

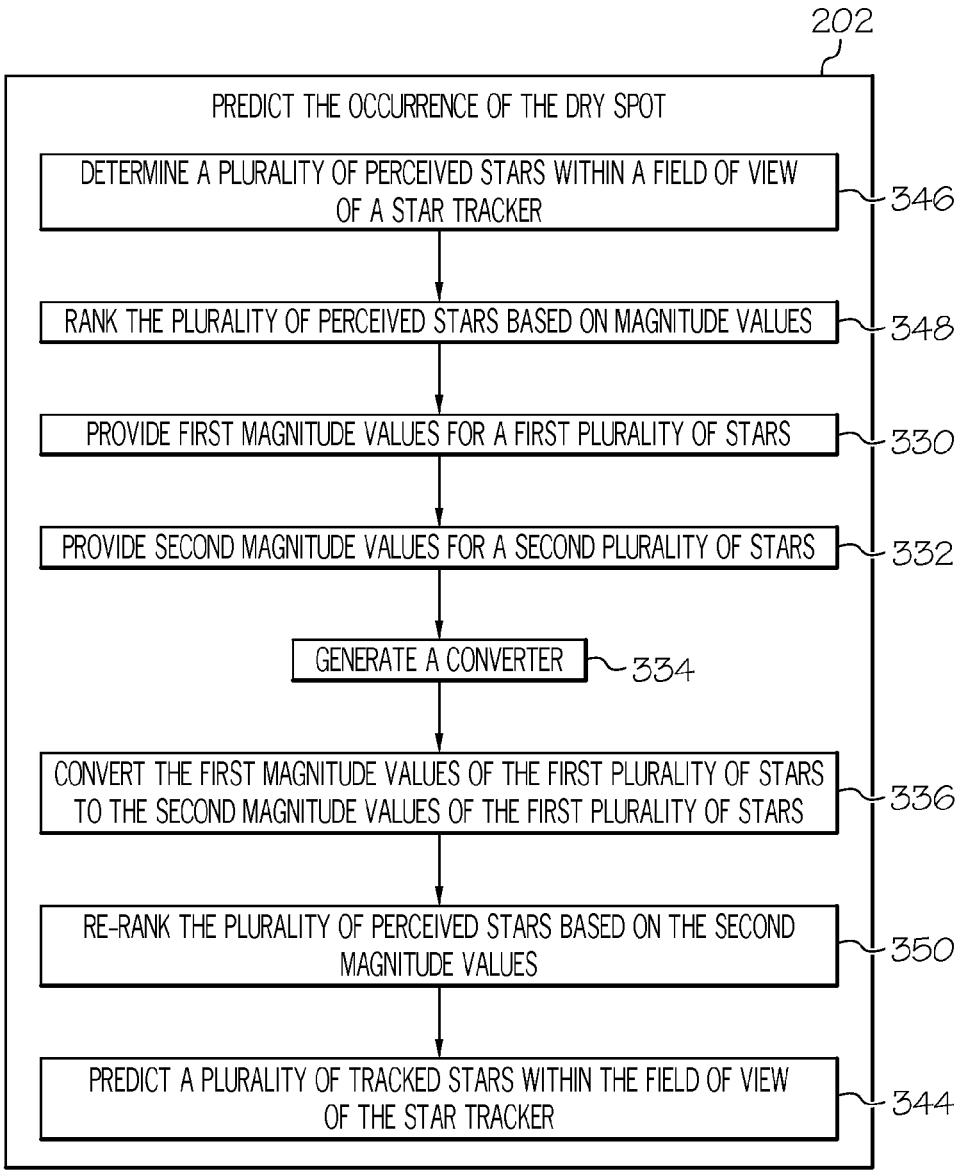

202
PREDICT THE OCCURRENCE OF THE DRY SPOT
DETERMINE A PLURALITY OF PERCEIVED STARS WITHIN A FIELD OF VIEW OF A STAR TRACKER
346
RANK THE PLURALITY OF PERCEIVED STARS BASED ON MAGNITUDE VALUES
348
PROVIDE FIRST MAGNITUDE VALUES FOR A FIRST PLURALITY OF STARS
330
PROVIDE SECOND MAGNITUDE VALUES FOR A SECOND PLURALITY OF STARS
332
GENERATE A CONVERTER
334
CONVERT THE FIRST MAGNITUDE VALUES OF THE FIRST PLURALITY OF STARS TO THE SECOND MAGNITUDE VALUES OF THE FIRST PLURALITY OF STARS
336
RE-RANK THE PLURALITY OF PERCEIVED STARS BASED ON THE SECOND MAGNITUDE VALUES
350
PREDICT A PLURALITY OF TRACKED STARS WITHIN THE FIELD OF VIEW OF THE STAR TRACKER
344

FIG. 18

SYSTEM AND METHOD FOR MITIGATING AN OCCURRENCE OF A DRY SPOT IN A FIELD OF VIEW OF A STAR TRACKER

FIELD

The present disclosure is generally related to star trackers and, more particularly, to a system and method for mitigating an occurrence of less than a minimum number of stars being identified by a star tracker (i.e., a dry spot in a field of view of the star tracker) by modifying a star catalog.

BACKGROUND

Aerospace vehicles are used for a variety of different purposes. For example, aircraft (e.g., both manned and unmanned), spacecraft (e.g., both manned and unmanned), unmanned aerial vehicles ("UAV") and satellites are in widespread use for various purposes including communications, scientific research and other civil and military applications. However, many aerial missions may not be accurately fulfilled without consistently monitoring and controlling a 3-axis attitude of the vehicle.

Attitude may be described as the vehicle orientation with respect to some external reference frame. In many applications, the vehicle must be oriented to transmit signals in particular directions and/or to receive signals from specifically located sources. Without accurate control over the vehicle 3-axis attitude, the transmission and/or reception of such signals may be hindered and, at times, may be impossible.

Such control may require systems for 3-axis attitude, which generally include one or more star trackers. During normal operation, star trackers may provide attitude-related information. As there may be inherent, and time-varying, errors from star trackers, it may be necessary to constantly estimate such errors, in order to compensate for them. One method of doing so is to identify stars tracked by the star tracker and correlate the star tracker position measurements of the stars with known positions of the same stars, as listed in an onboard star catalog.

When a star tracker is pointed at a region in the sky where the attitude determination system cannot identify a minimum number of stars for a predetermined period of time, the vehicle attitude may be properly maintained and/or a vehicle fault may occur. Such a region may be defined to be a "dry spot".

When the star tracker cannot identify a minimum number of stars for a predetermined period of time, a dry spot may occur and the vehicle attitude may not be properly maintained and/or a vehicle fault may occur.

Accordingly, those skilled in the art continue with research and development efforts in the field of star trackers to minimize or eliminate the occurrences of less than a minimum number of stars being identified by a star tracker.

SUMMARY

In one embodiment, the disclosed method for mitigating an occurrence of a dry spot may include the steps of: (1) predicting the occurrence of the dry spot, and (2) modifying a star catalog to reduce an impact of the dry spot.

In one embodiment, the disclosed method may include the step of: generating a visualization of the occurrence of the dry spot.

In one embodiment, the disclosed method may include at least one of the steps of: (1) determining a location of the occurrence of the dry spot, (2) determining a date of the occurrence of the dry spot, and/or (3) determining a duration of the occurrence of the dry spot.

In one embodiment, the disclosed method may include at least one of the steps of: (1) generating a set of modification to modify the star catalog, (2) generating a modification schedule for modifying the star catalog, and/or (3) uploading the set of modifications to the star catalog.

In one embodiment, the disclosed system for mitigating an occurrence of a dry spot may include: at least one computing device, and a non-transitory medium storing instructions that, when executed by the at least one computing device, causes the at least one computing device to: (1) predict the occurrence of the dry spot, and (2) modify a star catalog to reduce an impact of the dry spot.

Other embodiments of the disclosed system and method for mitigating an occurrence of a dry spot will become apparent from the following detailed description, the accompanying drawings and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic perspective view of one embodiment of a system for determining stars in a field of view of a star tracker;

FIG. **2** is a schematic block diagram of one embodiment of an apparatus for controlling the system represented FIG. **1**;

FIG. **3** is a block diagram of one embodiment of the star catalog represented in FIG. **2**;

FIG. **4** is a schematic illustration of one embodiment of the field of view represented in FIG. **2**;

FIG. **5** is a flow diagram of one embodiment of the disclosed method for mitigating an occurrence of a dry spot;

FIG. **6** is a flow diagram of one embodiment of the method for generating the visualization of the occurrence of the dry spot represented in FIG. **5**;

FIG. **7** is a schematic illustration of one embodiment of the visualization of the occurrence of the dry spot;

FIG. **8** is a schematic block diagram of one embodiment of a computer system for implementing the disclosed method represented in FIG. **5**;

FIG. **9** is a schematic block diagram of one embodiment of the method for predicting the occurrence of the dry spot represented in FIG. **5**;

FIG. **10** is a schematic block diagram of one embodiment of the method for modifying the star catalog represented in FIG. **5**;

FIG. **11** is a flow diagram of one embodiment of the method for determining the location of the occurrence of the dry spot represented in FIG. **9**;

FIG. **12** is a flow diagram of one embodiment of the method for determining the date of the occurrence of the dry spot represented in FIG. **9**;

FIG. **13** is a flow diagram of one embodiment of the method for determining the duration of the occurrence of the dry spot represented in FIG. **9**;

FIG. **14** is a flow diagram of one embodiment of the method for generating the set of modifications to modify the star catalog as represented in FIG. **10**;

FIG. **15** is a flow diagram of one embodiment of the method for determining whether the modification star entry can modify the star catalog as represented in FIG. **14**;

FIG. **16** is a flow diagram of one embodiment of the method for determining whether the modification star entry can modify the star catalog as represented in FIG. **14**;

FIG. **17** is a flow diagram of one embodiment of the method for generating the modification schedule for modifying the star catalog as represented in FIG. **10**; and

FIG. **18** is a flow diagram of one embodiment of the method for predicting the occurrence of the dry spot as represented in FIG. **1**.

DETAILED DESCRIPTION

The following detailed description refers to the accompanying drawings, which illustrate specific embodiments of the disclosure. Other embodiments having different structures and operations do not depart from the scope of the present disclosure. Like reference numerals may refer to the same element or component in the different drawings.

Referring generally to FIGS. **1-18**, disclosed is a system **116** and method **200** for mitigating an occurrence of a dry spot, generally designated **38**, in a field of view **42** of a star tracker **28**. As used herein, the term "dry spot" may define a location (e.g., in the sky) where less than the minimum number of identified stars **52** are present within the field of view **42** of the star tracker **28** for a period of time **136** (e.g., between at a given pair of attitudes **134** of an attitude history of the vehicle **12**). As one example, and as will be described in more detail herein below, the dry spot **38** may include any location where a minimum number of star entries **50***a* in a star catalog **34** do not correspond to a plurality of tracked stars **90** tracked by the star tracker **28** (e.g., within the field of view **42** of the star tracker **28**) between the pair of attitudes **134** of the vehicle **12** (e.g., are not identified stars **52***a*).

Referring to FIG. **1**, one embodiment of the disclosed system, generally designated **10**, for determining stars in a field of view of a star tracker field of a vehicle may include one or more vehicles **12** (only one vehicle **12** is illustrated in FIG. **1**). The system **10** may be in communication (e.g., transmitting signals **24** to and/or receiving signals **24** from), for example, with a station **14** on the Earth **16**. The vehicle **12** may include an apparatus **18** for determining and/or controlling inertial attitude and/or angular velocity of the vehicle **12** based, in whole or in part, upon measurements of positions of a plurality of stars **20** (designated individually as star **20***a*).

While the vehicle **12** is illustrated herein, by example, as a satellite, those skilled in the art will recognize that the vehicle **12** may include any vehicle that utilizes a star tracker (or star sensor) to aid in determining the attitude of the vehicle **12** including, but not limited to, aircraft, spacecraft, unmanned aerial vehicles ("UAV") and satellites.

As used herein, attitude **134** may be described as the orientation of the vehicle **12** with respect to a separately defined external frame, for example, an Earth-Centered Inertial ("ECI") coordinate frame **22** of the Earth **16**.

The ECI coordinate frame **22** may include a Cartesian coordinate system representing positions as an X, Y, and Z coordinate. For example, an X-axis may be permanently fixed in a direction relative to the Earth **16** (e.g., does not rotate as the Earth rotates). A Y-axis may be normal to the X-axis (e.g., lies at a 90° angle with respect to the X-axis) defining an X-Y plane coinciding with an equatorial plane of the Earth **16**. A Z-axis may be normal to both the X-axis and Y-axis (e.g., lies at a 90° angle with respect to the X-Y plane) and extends through the North Pole. Those skilled in the art will recognize that due to forces exerted from the sun and moon, the Earth's equatorial plane may move with respect to the celestial sphere. While the Earth **16** may rotate, the ECI coordinate frame **22** may not move.

The vehicle **12** may include a vehicle coordinate frame **26**. The vehicle coordinate frame **26** may include a Cartesian coordinate system representing positions as an X, Y, and Z coordinate. The vehicle coordinate frame **26** may be arbitrarily chosen or may be defined relative to the body of the vehicle **12**. For example, an X-axis may be fixed in a direction relative to the vehicle **12**. A Y-axis may be normal to the X-axis. A Z-axis may be normal to both the X-axis and Y-axis.

As one example, the Y-axis of the vehicle coordinate frame **26** may be oriented in the same direction as the Y-axis of the ECI coordinate frame **22**. Thus, attitude **134** may refer to the angular orientation of the vehicle coordinate frame **26** with respect to the ECI coordinate frame **22**.

Referring to FIG. **2**, in one embodiment, the apparatus **18** may locate stars **20***a* within or near the field of view **42** of the star tracker **28** in order to aid in determining and/or controlling the attitude and/or angular velocity of the vehicle **12**. Many scientific and/or communications missions may not be accurately fulfilled without consistently monitoring and controlling the vehicle 3-axis attitude and/or angular velocity. In many applications the vehicle **12** must be oriented to transmit signals **24** in particular directions or to receive signals **24** (FIG. **1**) from specifically located sources (e.g., the station **14**). Without accurate control over vehicle 3-axis attitude and/or angular velocity, the transmission or reception of such signals **24** may be hindered and at times may be impossible.

The apparatus **18** may include one or more star trackers (or star sensors) **28**, one or more gyroscopes **44** (e.g., a 3-axis gyroscope), and/or one or more processors **30**. The apparatus **18** may include a memory **32** coupled to the processor **30**. The memory **32** may include a star catalog **34**, which may be an astronomical database or portion thereof. The apparatus **18** may include an attitude and/or angular velocity control system **40** coupled to the processor **30**. Those skilled in the art will recognize that the processor **30** and/or the memory **32** may be physically on the vehicle **12** or may be remotely coupled to the vehicle, for example, from the ground station **14** (FIG. **1**).

Referring to FIG. **3**, in one embodiment, the star catalog **34** may be a database including a plurality of star entries **50** (designated individually as star entry **50***a*). Each star entry **50***a* of the plurality of star entries **50** may correspond to a particular star **20***a* of the plurality of stars **20**. Those skilled in the art will recognize that the plurality of star entries **50** contained by the star catalog **34** may be limited to a predetermined number of star entries **50***a*. As one example, the stars entries **50***a* selected for inclusion in the star catalog **34** may be limited due to inherent size limitations of the star catalog **34** and/or the memory **30**. As one example, the star entries **50***a* selected for inclusion in the star catalog **34** may be limited to star entries **50***a* corresponding only to stars **20***a* having desirable properties. Stars **20***a* having undesirable (e.g., exclusionary) properties may be excluded from inclusion into the star catalog **34**. For example, undesirable properties may include, but are not limited to: if a star **20***a* moves with respect to a celestial sphere at a relatively high rate (e.g., the position of the star **20***a* changes fast enough to potentially cause problems with attitude determination); if the star **20***a* (e.g., target star) has a near neighbor (e.g., another star **20***a* that is nearby or appears nearby when viewed from Earth) that may be mistaken for the target star; if the star **20***a* has a magnitude that varies widely over time, making the star **20***a* difficult to identify; and the like. Thus, every star **20***a* of the plurality of stars **20** in the sky may not be represented by a star entry **50***a* in the star catalog **34**.

In one example implementation, the plurality of star entries **50** contained in the star catalog **34** may be selected from a main star database **88** (FIG. **8**), which may be an astronomical database or portion thereof. The main star database **88** may include a plurality of star entries **50** corresponding to the plurality of stars **20** (e.g., to known stars **20***a*). The plurality of star entries **50** selected from the main star database **88** for inclusion in the star catalog **34** may represent the stars **20***a* of the plurality of stars **20** that are predicted to be (e.g., most likely to be) tracked by the star tracker **28** at a given attitude **134**.

Each star entry **50***a* may include star data **82**. The star data **82** may include a plurality of metrics **70** (designated individually at metric **70***a*) corresponding to the plurality of stars **20**. Each metric **70***a* may correspond to a particular star **20***a* of the plurality of stars **20**. Each metric **70***a* may include a value **66**. As one example, the plurality of metrics **70** may include at least one of: a right ascension angle **72** of the star **20***a* in a given ECI coordinate frame **22**, a declination angle **74** of the star **20***a* in the given ECI coordinate frame **22**, a magnitude **76** of the star **20***a*, a star vector **78**, an identification number **80** of the star **20***a*, and/or other metrics **70***a* (e.g., properties) of the star **20***a*.

In one example implementation, the plurality of star entries **50** may be sorted by the star data **82** (e.g., by one or more metrics **70***a* of the plurality of metrics **70***a*). As one example, the star data **82** may be stored using a primary and multiple secondary arrays. As one example, the star data **82** may be sorted by at least one of the declination angle **74** and/or the right ascension angle **72**. As one example, each primary array element may point to separate secondary arrays, which may contain star data **82** (e.g., magnitude **76**, star vector **78**, and/or identification number **80**) for all the stars **20***a* that are between the current and the primary array next element. As one example, the stars **20***a* in the primary array may be sorted by declination angles **74** ranging, for example, from negative ninety to positive ninety degrees. As one example, the stars **20***a* in the secondary arrays may be sorted by their right ascension, for example, from zero to three hundred-sixty degrees.

Referring to FIGS. **1** and **2**, in one embodiment, the star tracker **28** may be mounted to the vehicle **12**. The star tracker **28** may include a field of view ("FOV") **42** and a boresight **46** centered in the field of view **42**. The star tracker **28** may be coupled to the processor **30**. The star tracker **28** may locate a plurality of stars **20** (e.g., sense a position of one or more stars **20***a*) within or near the field of view **42** of the star tracker **28** in order to aid in controlling the attitude of the vehicle **12**. As one example, the plurality of stars **20** within or near the field of view **42** may be defined by the stars **20***a* located within a frame defined by the field of view **42** of the star tracker **28** with respect to the vehicle **12** (e.g. to the vehicle coordinate frame **26**). The star tracker **28** may generate a plurality of signals corresponding to the plurality of positions of the plurality of stars **20** in the field of view **28**. The plurality of signals may include position measurement data for the plurality of stars **20**. The star tracker **28** may transmit the signals (e.g., position measurement data) to the processor **30** in a conventional manner.

The processor **30** may receive the plurality of signals corresponding to the plurality of positions (e.g., locations) of the plurality of stars **20** within the field of view **42** of the star tracker **28**. The processor **30** may provide control logic operative to select at least one signal of the plurality of signals corresponding to the position (e.g., location) of one or more stars **20***a* of the plurality of stars **20**.

For simplification purposes, the processor **30** is illustrated as a single component; however, the processor **30** may be an individual processor or may include of a plurality of processors. For example, each star tracker **28** may include its own processor **30**. Similarly, the gyroscope **44** and/or the attitude and/or angular velocity control system **40** may include its own processor **30**, for example, a spacecraft control processor ("SCP"). As one example, each processor **30** may be microprocessor-based.

The memory **32** may include a single element or multiple element memory system. As one example, the memory may include various types of memory elements including, but not limited to, random access memory ("RAM"). Additionally, if the processor **30** is microprocessor-based, the microprocessor may include its own memory therein (not shown).

The processor **30** may be coupled to the attitude and/or angular velocity control system **40**. The attitude and/or angular velocity control system **40** may include a plurality of actuators (e.g., thrusters or momentum wheels) utilized in a conventional manner. The attitude and/or angular velocity control system **40** may control the various actuators to orient the vehicle **12** in its desired direction.

In one embodiment, more than one star tracker **22** may be included on a vehicle. As one example, the apparatus **18** may include at least one redundant star tracker **28** and/or at least one redundant processor **30**. As one specific, non-limiting example, for a given vehicle **12** that requires two star trackers **28** and one processor **30** for normal operation, the vehicle **12** may include three star trackers **28** (e.g., two primary star trackers and one redundant star tracker) and two processors **30** (e.g., one primary processor and one redundant processor).

Referring still to FIGS. **1** and **2**, during normal operation of the vehicle **12**, the star tracker **28** may provide attitude-related information to the processor **30** and the gyroscope **44** may provide angular velocity information to the processor **30**. As there may be inherent, and time-varying, errors from the star tracker **28** and/or the gyroscope **44**, it may be necessary to constantly estimate such errors, in order to compensate for the errors. One example operation or procedure for estimating such errors may include correlating the position measurement data (e.g., from the star tracker **28**) of one or more stars **20***a* of the plurality of stars **20** with known positions of the same stars **20***a*, as listed in the star catalog **34**. Discrepancies between the measured position and predicted (e.g., known) position of the star **20***a* may allow for direct or indirect estimation of star tracker error and/or gyroscopic error. Determination of such errors may allow for estimation of attitude and/or angular velocity or may allow for refinement of existing estimates.

Furthermore, if there are multiple star trackers **28** onboard the vehicle **12**, such correlations may allow for the determination of the alignment of such star trackers **28** with respect to each other. Such determination may yield greater accuracy in future attitude and/or angular velocity estimates.

Operations or procedures for estimating errors from the star tracker **28**, such as those described above, may require a method for obtaining a coarse estimate of the attitude of the vehicle **12**, where, for example, attitude is considered to be the orientation of the vehicle reference frame **26** with respect to the ECI coordinate frame **22**. One example method may generally include two steps, as described below.

The first step of such a method for obtaining a coarse estimate of the attitude of the vehicle **12** may be to identify the stars **20***a* of the plurality of stars **20** detected by the star tracker **28** as known stars from the star catalog **34** (e.g., the

star catalog **34** includes star entries **50***a* corresponding to the stars **20***a*). Each star entry **50***a* of the star catalog **34** may contain information (e.g., star data **82**) about the particular corresponding star **20***a* of the plurality of stars **20**, such as the position (e.g., location) of the star **20***a* with respect to the ECI coordinate frame **22**. In one example implementation, each star entry **50***a* may be associated with a star catalog index allowing for location of the star entry **50***a* (e.g., by the processor **30**).

Referring to FIGS. **2** and **4**, as one example, the star tracker **28** may sense and/or detect a plurality of perceived stars **48** (designated individually as perceived star **48***a*). As used herein, the plurality of perceived stars **48** may include a subset of the plurality of stars **20** (e.g., one or more stars **20***a* of the plurality of stars **20**) that are within the field of view **42** of the vehicle **12** at the given attitude **134** or between the given pair of attitudes **134** of the vehicle **12**. In one example implementation, the plurality of star entries **50** selected for inclusion in the star catalog **34** may be a best representation of at least a portion of the plurality of perceived stars **48** predicted to be within the field of view **42** of the vehicle **12** at the given attitude **134** of the vehicle **12**.

In one example implementation, in order to find which stars **20***a* of the plurality of stars **20** are within the field of view **42** (e.g., which stars **20***a* are perceived stars **48***a*), a minimum declination angle **96** for the field of view **42** may be calculated from the estimated attitude of the vehicle **12**. Starting from a declination strip containing the minimum declination angle **96**, a binary search may be performed to find a minimum right ascension angle **98** for the field of view **42**. Until the maximum right ascension angle **98** is reached, each star **20***a* may be determined whether it is within the field of view **42**. As one example, determining the plurality of stars **20** within the field of view **42** of the star tracker **28** at the attitude **134** of the plurality of attitudes (e.g., of the attitude history) of the vehicle **12** may include determining a location of the boresight **46** of the star tracker **28** relative to the attitude **134** of the vehicle **12**. A limit to the field of view **42** of the star tracker **28** may be determined. A position (e.g., location) of the star **20***a* of the plurality of stars **20** relative to the field of view **42** may be determined, then whether the position of the star **20***a* is within the field of view **42** may be determined, and the star **20***a* may then be designated as a perceived star **48***a*. This operation may be repeated until all possible declination strips have been searched and all possible perceived stars **48***a* have been identified and/or designated.

The star tracker **28** may track a plurality of tracked stars **90** (designated individually as tracked star **90***a*). As used herein, the plurality of tracked stars **90** may include a subset of the plurality of perceived stars **48** (e.g., one or more perceived stars **48***a* of the plurality of perceived stars **48**). The remaining perceived stars **48***a* of the plurality of perceived stars **48** within the field of view **42** of the star tracker **28** may be untracked stars **92**. The star tracker **28** may automatically choose which perceived stars **48***a* of the plurality of perceived stars **48** to track (e.g., which perceived stars **48***a* are tracked stars **90***a*). In one example implementation, the plurality of star entries **50** selected for inclusion in the star catalog **34** may be a best representation of at least a portion of the plurality of tracked stars **90** predicted to be tracked by the star tracker **28** at the given attitude **134** of the vehicle **12**.

Those skilled in the art will recognize that the particular number of tracked stars **90***a* tracked by the star tracker **28** may depend on the type of star tracker **28** being used by the vehicle **12**. As one example, at least three perceived stars **48***a* may be tracked stars **90***a*. As one example, at least five perceived stars **48***a* may be tracked stars **90***a*. As one example, at least eight perceived stars **48***a* may be tracked stars **90***a*. As one example, at least ten perceived stars **48***a* may be tracked stars **90***a*.

In one example implementation, the plurality of tracked stars **90** may include one or more of the perceived stars **48***a* having a brightness value **100** (e.g., brightness) sufficiently appreciable for the star tracker **28** to recognize and track. As one example, the plurality of tracked stars **90** may include one or more of the perceived stars **48***a* having the greatest brightness value **100** (e.g., the brightest) of the plurality of perceived stars **48**. Those skilled in the art will recognize that the star tracker **28** may tend to automatically choose and/or track the brightest perceived stars **48***a* of the plurality of perceived stars **48**.

The star tracker **28** and the processor **30** may determine the position (e.g., location) of one or more tracked stars **90***a* of the plurality of tracked stars **90**. As one example, the star tracker **28** may determine the position of one or more tracked stars **90***a* of the plurality of tracked stars **90** relative to the star tracker **28** (e.g., relative to the vehicle coordinate frame **26**). In order to determine the position (e.g., location) of the plurality of tracked stars **90**, the star tracker **28** may need to identify one or more of the tracked stars **90***a*. The plurality of tracked stars **90** that are identified by the star tracker **28** may define a plurality of identified stars **52** (designated individually as identified star **52***a*). As used herein, the plurality of identified stars **52** may include a subset of the plurality of tracked stars **90** (e.g., one or more tracked stars **90***a* of the plurality of tracked stars **90**) that have corresponding star entries **50***a* in the star catalog **34**.

The second step of such a method for obtaining a coarse estimate of attitude of the vehicle **12** may be to use the following to obtain the estimate of the attitude of the vehicle **12**: (1) the knowledge of the position (e.g., location) of the star **20***a* (e.g., the identified star **52***a*) with respect to the ECI coordinate frame **22**, which may be represented by star data **82** of the star entry **50***a* in the star catalog **34**; (2) the knowledge of the position (e.g., location) of the star **20***a* (e.g., the identified star **52***a*) in the field of view **42** of the star tracker **28**, which is output by the star tracker **28**; and (3) the knowledge of the alignment of the star tracker **28** with respect to the vehicle coordinate frame **26** (e.g. the vehicle body).

In order to properly estimate error and/or aid in maintaining the coarse attitude of the vehicle **12**, it may be necessary for a minimum number of identified stars **52***a* to be present within the field of view **42** of the star tracker **28** at the given attitude and/or between the given pair of attitudes (e.g., the star tracker **28** may need to identify a minimum number of tracked stars **90***a* corresponding to particular star entries **50***a* in the star catalog **34**). Accordingly, in order to identify the minimum number of identified stars **52***a*, the star catalog **34** must contain a minimum number of star entries **50***a* corresponding to the tracked stars **90***a* (e.g., a minimum number of tracked stars **90***a*) within the field of view **42** of the star tracker **28**.

Those skilled in the art will recognize that the particular minimum number of identified stars **52***a* required in order to estimate error and/or aid in maintaining the coarse attitude of the vehicle **12** may depend on the type of star tracker **28** being used by the vehicle **12**. As one example, at least two identified stars **52***a* must be present (e.g., a minimum of two star entries **52***a* must correspond to the plurality of tracked stars **90**). As one example, at least three identified stars **52***a* must be present (e.g., a minimum of three star entries **52***a*

must correspond to the plurality of tracked stars **90**). As one example, at least five identified stars **52***a* must be present (e.g., a minimum of five star entries **52***a* must correspond to the plurality of tracked stars **90**).

If the minimum number of identified stars **52***a* is not present within the field of view **42** of the star tracker **28** (e.g., if star tracker **28** cannot identify a minimum number of tracked stars **90***a* corresponding to the minimum number of star entries **50***a* in the star catalog **34**), a dry spot **38** may occur and the coarse attitude of the vehicle **12** may not be properly maintained, thus, potentially interrupting reception and/or transmission of signals **24** (FIG. **1**) and/or causing a fault to occur on the vehicle **12**. As one example, if the minimum number of identified stars **52***a* is not present within the field of view **42** of the star tracker **28** for a pre-set period of time **136**, a fault may occur. In response to the fault, the vehicle **12** may automatically execute a response; such as, the apparatus **18** may switch from the primary star tracker to the secondary star tracker or the apparatus **18** may switch from the primary processer to the secondary processor.

Those skilled in the art will recognize that the period of time **136** where the minimum number of identified stars **52***a* is not present, the type of fault (e.g., a fault count), and/or the corrective action executed in response to the fault may depend on the type of vehicle **12** (e.g., spacecraft), the type of star tracker **28**, and/or the on-board logic of the processor **30**.

Generally, the dry spot **38** may occur when the star catalog **34** does not include at least the minimum number of star entries **50***a* corresponding to the plurality of tracked stars **90** within the field of view **42** of the star tracker **28** between the given pair of attitudes **134** (e.g., during the period of time **136**). For example, in order to operate normally, the star tracker **28** may require the minimum number of identified stars **52***a* (e.g., at least the minimum number of star entries **52***a* in the star catalog **34** corresponding to the plurality of tracked stars **90**).

In one example implementation, the star tracker **28** may track the plurality of tracked stars **90***a*. When the star catalog **34** includes at least the minimum number of star entries **50***a* corresponding to the plurality of tracked stars **90** (e.g., the minimum number of tracked stars **90***a* identified by the star tracker **28** is greater than the minimum number of identified stars **52***a* required), then the star tracker **28** may properly estimate error and/or aid in maintaining the coarse attitude of the vehicle **12**. When the star catalog **34** does not includes at least the minimum number of star entries **50***a* corresponding to the plurality of tracked stars **90** (e.g., the minimum number of tracked stars **90***a* identified is less than the minimum number of identified stars **52***a* required), then the star tracker **28** may not properly estimate error and/or aid in maintaining the coarse attitude of the vehicle **12**.

Those skilled in the art will recognize that various factors may tend to lead to the occurrence of one or more dry spots **38** between the given pair of attitudes **134** of the vehicle **12** (i.e., where less than the minimum number of identified stars **52***a* are present within the field of view **42** for the period of time **136**).

As one example, the star tracker **28** may not distinguish between those tracked stars **90***a* having a corresponding star entry **50***a* in the star catalog **34** (e.g., the tracked stars **90***a* that are identified stars **52***a*) and those tracked stars **90***a* not having a corresponding star entry **50***a* in the star catalog **34** (e.g., the tracked stars **90***a* that are unidentified stars). Thus, a portion of the plurality of tracked stars **90** tracked by the star tracker **28** may not have corresponding star entries **50***a*, which may lead to less than the minimum number of tracked stars **90***a* being identified and creating the occurrence of the dry spot **38**.

As one example, the plurality of star entries **50** selected for inclusion in the star catalog **34** as the best representation of the predicted plurality of tracked stars **90** may not represent the actual plurality of tracked stars **90** tracked by the star tracker **28** at the given attitude **134** and/or between the given pair of attitudes **134**. For example, a star entry **50***a* may be selected from the main star database **88** (e.g., for inclusion into the star catalog **34**) based on a known (e.g., reported) magnitude (e.g., brightness value) of the star **20***a*. As one example, the selected star entry **50***a* may be chosen as one of the brightest perceived star **48***a* within the field of view **42** of the star tracker **28** and, thus, likely to be a tracked star **90***a*. However, the magnitude of the perceived star **48***a* may vary or change over time and/or the reported magnitude of the perceived star **48***a* may be incorrect. As one example, the observed magnitude (e.g., brightness value) of the perceived star **48***a* may be less than another local perceived star **48***a* (e.g., a near neighbor) within the field of view **42** and, thus, the star tracker **28** may track the brighter perceived star **48***a* (e.g., tracked star **90***a*), which may not have a corresponding star entry **50***a* (e.g., is not an identified star **52***a*) and which may lead to less than the minimum number of star entries **52***a* corresponding to the plurality of tracked stars **90** and creating the occurrence of the dry spot **38**.

As one example, the star tracker **28** may lose a tracked star **90***a* at any time, for example, due to a proton hit. When the star tracker **28** tracks less a minimum number of tracked stars **90***a* (e.g., as determined by the star tracker **28**), it may resume tracking a previously untracked star **92**. For example, this may be due to the star tracker **28** choosing an available perceived star **48***a* within the field of view **42** having the greatest brightness value. However, the newly tracked star **90***a* (i.e., the previously untracked star **92**) may not have a corresponding star entry **64** contained in the star catalog **34** (e.g., is not an identified star **52***a*), which may lead to less the minimum number of star entries **52***a* corresponding to the plurality of tracked stars **90** and creating the occurrence of the dry spot **38**.

Thus, the present disclosure recognizes and takes into account the advantages of mitigating the occurrences of the dry spots between the pair of attitudes **134** of the vehicle **12** over the period of time **136**.

Referring to FIG. **5**, and with reference to FIGS. **1-4**, one embodiment of the disclosed method, generally designated **200**, for mitigating the occurrence of the dry spot **38** may include predicting the occurrence of the dry spot **38**, (FIG. **4**) as shown at block **202**, determining whether the dry spot **38** may impact attitude determination performance of the vehicle **12** (e.g., the apparatus **18**), and modifying (e.g., repairing) the star catalog **34** (FIG. **3**) to reduce (e.g., limit or eliminate) an impact on the attitude determination performance of the vehicle **12** due to the dry spot **38**, as shown at block **204**. As described herein above, the impact of the dry spot **38** may include impacting the operation of the star tracker **28** to determine the attitude of the vehicle **12** and/or preventing the star tracker **28** from maintaining an attitude estimate of the vehicle **12** having a required accuracy.

Referring to FIG. **5**, and with reference to FIGS. **1**, **2**, **4**, and **7**, in one embodiment, the method **200** may include generating a visualization **84** (FIG. **7**) of the occurrence of the dry spot **38** (FIG. **4**), as shown at block **244**.

Referring to FIG. **6**, and with reference to FIGS. **1**, **2**, **4**, and **7**, generating the visualization **84** of the occurrence of the dry spot **38** (block **244**) may include generating a plot

138. The plot 138 (FIG. 7) may including a plurality of points of right ascension 98 and declination 96 to which the boresight 46 (FIG. 2) of the star tracker 28 points at a plurality of attitudes 134 (FIG. 7) of the vehicle 12 (FIG. 1).

As shown at block 276, whether the plurality of tracked stars 90 within the field of view 42 of the star tracker 28 corresponds to a minimum number of star entries 50*a* in the star catalog 34 at each point of the plurality of points may be determined.

As one example implementation, and used throughout the present disclosure, determining whether the plurality of tracked stars 90 within the field of view 42 of the star tracker 28 corresponds to a minimum number of star entries 50*a* in the star catalog 34 may include determining whether the plurality of tracked stars 90 within the field of view 42 includes a minimum number of stars 20*a* represented in the star catalog 34 as star entries 50*a* (e.g., are identified stars 52*a*) required to aid in determining the attitude of the vehicle 12, properly estimate error, and/or aid in maintaining the coarse attitude of the vehicle 12. The star catalog 34 may include star entries 50*a* representing a plurality of stars 20. The minimum number star entries 50*a* (e.g., the required minimum number of star entries 50*a*) may be based on the minimum number of identified stars 52*a* (e.g., the tracked stars 90*a* having a corresponding star entry 50*a* in the star catalog 34) required to properly estimate error and/or aid in maintaining the coarse attitude of the vehicle 12.

As one example, if the star catalog 34 includes the required minimum number of star entries 50*a* representing the stars 20*a* being tracked by the star tracker 28 (e.g., the tracked stars 90*a*), then plurality of tracked stars 90 within the field of view 42 of the star tracker 28 does correspond to the minimum number of star entries 50*a* in the star catalog 34. As one example, if the star catalog 34 does not include the required minimum number of star entries 50*a* representing the stars 20*a* being tracked by the star tracker 28 (e.g., the tracked stars 90*a*), then plurality of tracked stars 90 within the field of view 42 of the star tracker 28 does not correspond to the minimum number of star entries 50*a* in the star catalog 34.

As shown at block 278, each point may be coded based upon the determination of whether the minimum number of star entries 50*a* in the star catalog 34 corresponds to the plurality of tracked stars 90.

In one example implementation, the coding operation (block 278) may include color-coding each point on the plot 138. As one example, when a determination is made that more than the minimum number of star entries 50*a* correspond to the plurality of tracked stars 90, that point may be coded with a first color (e.g., blue). Points coded with the first color may visually represent an attitude 134 where a high number of the tracked stars 90*a* are identified stars 52*a* and, thus, a dry spot 38 is unlikely to occur. As one example, when a determination is made that the minimum number of star entries 50*a* correspond to the plurality of tracked stars 90, that point may be coded with a second color (e.g., yellow). Points coded with the second color may visually represent an attitude 134 where a low number of tracked stars 90*a* are identified stars 52*a*, but a dry spot 38 is unlikely to occur. As one example, when a determination is made that less than the minimum number of star entries 50*a* correspond to the plurality of tracked stars 90, that point may be coded with a third color (e.g., red). Points coded with the third color may visually represent an attitude 134 where too few tracked stars 90*a* are identified stars 52*a* and, thus, a dry spot 38 is likely to occur.

As shown at block 280, a visual representation 132 of the dry spot 38 may be generated based on the plurality of coded points on the plot 138. As one example, a plurality of points coded with the first color may define a visual representation 140 of an area where more than the minimum number of star entries 50*a* corresponds to the plurality of tracked stars 90 (e.g., a safe area). As one example, a plurality of points coded with the second color may define a visual representation 142 of an area where the minimum number of star entries 50*a* corresponds to the plurality of tracked stars 90 (e.g., a safe area). As one example, a plurality of points coded with the third color may define a visual representation 132 of an area where less than the minimum number of star entries 50*a* corresponds to the plurality of tracked stars 90 (e.g., the dry spot 38). One or more visual representations 132 (identified individually as visual representations 132*a*, 132*b*) of dry spots 38 may be included on the same visualization 84.

As shown at block 282, a visual representation 130 of the trajectory of the boresight 46 of the star tracker 28 may be generated. The trajectory of the boresight 46 may be determined by declination 96 and right ascension 98 of the boresight 46 at the plurality of attitudes 134 of the vehicle 12. As one example, the visual representation 130 of the trajectory may represent the declination 96 and right ascension 98 at which the boresight 46 is pointed over the course of a time period (e.g., a year, a day, an hour, etc.). One or more visual representations 130 (identified individually as visual representations 130*a*, 130*b*, 130*c*, and 130*d*) of the trajectory of the boresight 46 may be included on the same visualization 84.

As one example, a first visual representation 130*a* may represent the trajectory of the boresight 46 over a first time period T1; a second visual representation 130*b* may represent the trajectory of the boresight 46 over a second time period T2; a third visual representation 130*c* may represent the trajectory of the boresight 46 over a third time period T3; and a fourth visual representation 130*d* may represent the trajectory of the boresight 46 over a fourth time period T4. Those skilled in the art will recognize that any number of visual representations 130 of the trajectory of the boresight 46 over any number of time periods may be included in the visualization 84.

As shown at block 284, whether the dry spot 38 will impact operation of the star tracker 28 may then be determined. As one example, such a determination may be made by determining whether the visual representation 130 of the trajectory of the boresight 46 intersects the visual representation 132 of the dry spot 38. For example, the visual representation 130 of the trajectory of the boresight 46 may be superimposed on the plot 138, as illustrated in FIG. 7. As depicted, the first visual representation 130*a* over the first time period T1, the second visual representation 130*b* over the second time period T2, and the third visual representation 130 over the third time period T3 do not intersect the visual representations 132*a*, 132*b* of the dry spot 38 and, thus, the dry spots 38 may not impact operation of the star tracker 28. The third visual representation 130 over the third time period T3 intersects the visual representation 142, however, there may be no impact on the operation of the star tracker 28 but the area represented by the visual representation 142 may be monitored and/or further investigated. The fourth visual representation 130*d* over the fourth time period T4 intersects the visual representation 132*a* of the dry spot 38 and, thus, that dry spot 38 may impact operation of the star tracker 28.

Thus, the visualization **84** may determine whether there are severe dry spots **38**, few dry spots **38**, or no dry spots **38** in an area and when there are dry spots **38**, if and/or how those dry spots **38** may impact the operation of the sky tracker **28**. Additionally, the visualization **84** may visually identify and/or predict the location of the occurrence of the dry spot **38**, the date of the occurrence of the dry spot **38**, and/or the duration of the occurrence of the dry spot **38** by the intersection of the visual representation **130** of a trajectory of the boresight **46** with the visual representation **132** of the dry spot **38**. As one example, the visual representation **132** of the dry spot **38** may represent the location (e.g., the right ascension and declination), the date (e.g., the date/time the boresight **46** enters the dry spot **38**), and/or the duration (e.g., the time period between the boresight **46** entering and exiting the dry spot **38**) of the occurrence of the dry spot **38** corresponding to the plurality of attitudes **134** of the vehicle **12**.

Referring to FIG. **9**, in one embodiment, predicting the occurrence of the dry spot **38** (block **202**) may include at least one of: determining a location of the occurrence of the dry spot **38**, as shown at block **206**; determining a date of the occurrence of the dry spot **38**, as shown at block **208**; and/or determining a duration of the occurrence of the dry spot **38**, as shown at block **210**.

Referring to FIG. **10**, in one embodiment, modifying the star catalog **34** of the star tracker **28** (block **204**) may include at least one of: generating a proposed set of modifications **36** to modify the star catalog **34**, as shown at block **212**; generating a modification schedule **68** for modifying the star catalog **34** with the set of modifications **36**, as shown at block **214**; and uploading the set of modifications **36** to the star catalog **34**, as shown at block **216**. As will be described in more detail herein, the set of modifications **36** may include one or more modification star entries **86***a* for modifying the plurality of star entries **50** of the star catalog **34**.

Referring to FIG. **8**, in one embodiment, the disclosed method **200** may be implemented by a computer system **116**, as shown by an exemplary hardware environment. As one example, the computer system **116** may include one or more computing device **118** (e.g., a computer) executing one or more computer programs **124** embodying the disclosed method **200**. Generally, the computing device **118** may include of one or more CPUs **120**, various amounts of memory **122** (e.g., RAM) storing the computer programs **124** and other data, and other components, such as those typically found in computers. In addition, the computing device **118** may include one or more monitors, fixed or removable data storage devices **126** (e.g., hard disk drives, floppy disk drives, and/or CD-ROM drives), and/or input devices (e.g., mouse pointing devices and/or keyboards).

The computing device **118** may operate under the control of an operating system (e.g., Windows, Macintosh, UNIX, or the like). Further, the computing device **118** may execute one or more computer programs **124** under the control of the respective operating systems. As one example, the disclosed method **200** may be implemented as one or more computer programs **124** executed by the computing device **118**, although those skilled in the art will recognize that the computer programs **124** may also be executed on a client or network computer.

Generally, the computer programs **124** implementing the disclosed method **200** may be tangibly embodied in a non-transitory computer-readable medium (e.g., one or more of the fixed and/or removable data storage devices **126** coupled to the computing device **118**). As one example, under control of the operating system, the computer program **124** may be loaded from the data storage devices **126** into the memory **122** of the computing device **118** for subsequent execution by the CPU **120**. The computer program **124** may include instructions that, when read and executed by the computing **118**, causes the computing device **118** to perform the steps, operations, and/or processes necessary to execute the steps, operations and/or elements of the disclosed method **200**.

Those skilled in the art will recognize that the hardware environment illustrated in FIG. **8** is not intended to be limiting. Those skilled in the art will recognize that other hardware environments may be used without departing from the scope of the present disclosure.

In one example implementation of the disclosed method **200**, a variety of information **56** (e.g., input data) may be provided to and/or generated by the computer programs **124** for execution by the computing device **118** as a variety of products **64** (e.g., output data). As one example, the information **56** may include, but is not limited to, attitude data **58**, perceived star data **60**, tracked star data **62**, the plurality of star entries **50** of the star catalog **34**, the star data **82** for each star entry **50***a*, exclusionary properties **144** for the star **20***a*, and/or the main star data base **88**. As one example, the product **64** may include, but is not limited to, the set of modifications **36**, the modification schedule **68**, and/or the dry spot visualization **84**.

Referring to FIG. **11**, in one embodiment, determining the location of the occurrence of the dry spot **38** (block **206**) may include determining a plurality of attitudes **134** of the vehicle **12**, as shown at block **218**.

In one example implementation, the plurality of attitudes **134** of the vehicle **12** may be determined from the attitude data **58** (FIG. **8**). As one example, the attitude data **58** may include discrete attitude information for the vehicle **12** at a given time coordinate of a plurality of time coordinates. The attitude **134** of the vehicle **12** may define the field of view **42** and the boresight **46** of the star tracker **28** at the time coordinate. The time coordinate may include a date/time set associated with each attitude **134**. As one example, the time period between a pair of time coordinates may define a portion of the flight of the vehicle (e.g., the period of time **136**). As one example, the plurality of time coordinates may define the full duration of flight of the vehicle **12**. For example, the duration of flight of the vehicle **12** may include a flight time from a beginning of life of the vehicle **12** to an end of life of the vehicle **12** (e.g., attitude history), for example, the flight time of a satellite.

As one example, the attitude data **58** may be provided, for example, from a reference list or index containing the attitude history of the vehicle **12**. As used herein, the attitude history may include a set of dates/times and an associated attitude **134** of the vehicle **12** (e.g., in quaternion form) for each date/time set. Thus, the attitude data **58** may include the plurality of time coordinates (e.g., date/time sets) and an associated plurality of attitudes **134** of the vehicle **12** at the plurality of time coordinates. As one example, each time coordinate of the plurality of time coordinates may be spaced apart by a time duration (e.g., an interval). As one example, the time duration may be no greater than 30 minutes. As one example, the time duration may be no greater than 15 minutes. As one example, the time duration may be no greater than 5 minutes. As one example, the time duration may be no greater than 1 minute. As one example, the time duration may be no greater than 30 seconds. As one example, the time duration may be no greater than 15 seconds. As one example, the time duration may be no

greater than 1 second. The time duration between each time coordinate of the plurality of time coordinates may be the same or may be different.

In certain cases, the time duration may be too large of an interval to adequately determine the location and/or duration of the dry spot **38** between a pair of attitudes **134**. If the time duration between time coordinates of first attitude data is too large, then second attitude data may be generated until the time duration is sufficiently small. As one example, first attitude data may be provided, for example, from the reference list or index containing the attitude history of the vehicle **12**. The first attitude data may include a plurality of first time coordinates and an associated plurality of first attitudes of the vehicle **12** at the plurality of first time coordinates. Each first time coordinate of the plurality of first time coordinates may be spaced apart by a first time duration, which is too large of an interval. The second attitude data may be generated from the first attitude data. As one example, generating the second attitude data may include interpolating the first attitude data. The second attitude data may include a plurality of second time coordinates (e.g., date/time sets) and an associated plurality of second attitudes of the vehicle **12** at the plurality of second time coordinates. Each first time coordinate and second time coordinate may be spaced apart by a second time duration (e.g., less than the first time duration), which is sufficiently small to adequately determine the location and/or duration of the dry spot **38** between a pair of attitudes **134**. The second time duration between each first and second time coordinate may be the same or may be different.

In certain cases the time duration between time coordinates ("ΔT") needs to be the same (e.g., the time coordinates need to be evenly spaced). As one example, if a first time coordinate (e.g., date/time set) is X, then the second time coordinate must be X+ΔT, the third time coordinate must the X+2ΔT, the fourth time coordinate must be X+3ΔT, etc. If the time duration between time coordinates of first attitude data (e.g., attitude data provided from the attitude history) is not the same (e.g., an irregular time duration), then second attitude data may be generated until the time duration between all the time coordinates (e.g., between the plurality of first time coordinates and the plurality of second time coordinates) of the attitude data **58** (e.g., the first attitude data and the second attitude data) is the same (e.g., a regular time duration). As one example, generating the second attitude data may include interpolating the first attitude data.

Thus, the operational step of determining the plurality of attitudes **134** of the vehicle **12** (block **218**) may provide attitude data **58** in the required form (e.g., evenly spaced time durations and/or sufficiently small time durations). Those skilled in the art will recognize that the total number of attitudes, the time duration between attitudes, and/or the length of the regular time duration between attitudes may depend upon various factors, such as, the type of vehicle **12** and/or star tracker **28**.

Referring still to FIG. **11**, as shown at block **220**, the star catalog **34** including the plurality of star entries **50** may be provided. In one example implementation, the star catalog **34** including the plurality of star entries **50** may be or may be a representation of the star catalog **34** included in the memory **32** of the apparatus **18** of the vehicle **12**. For example, the star catalog **34** may include the plurality of star entries **50** initially selected from the main star database **88**.

As shown at block **222**, the plurality of tracked stars **90** within the field of view **42** of the star tracker **28** may be determined at the plurality of attitudes **134**. In one example implementation, the plurality of tracked stars **90** within the field of view **42** of the star tracker **28** at the plurality of attitudes **34** may be determined from the perceived star data **60** and/or the tracked star data **62**.

As one example, the perceived star data **60** may be provided, for example, from a reference list of index containing a list of stars **20***a* known to be and/or predicted to be within the field of view **42** of the star tracker **28** (e.g., perceived stars **48***a*) at the plurality of attitudes **134** (block **218**). The plurality of tracked stars **90** may be generated from the perceived star data **60** (e.g., selected from the list of perceived stars **48***a*). As one example, the plurality of tracked stars **90** may be selected based on one or more metrics **70***a* contained in the star data **82**. As one example, the plurality of tracked stars **90** may be selected from the plurality of perceived stars **48** having the greatest brightness value **100** (e.g., the brightest stars **20***a* within the field of view **42** of the star tracker **28** at the attitude **134**), which are the perceived stars **48***a* most likely to be tracked by the star tracker **28**.

As one example, the tracked star data **62** may be provided, for example, from a reference list or index containing a list of the brightest perceived stars **48***a* known to be or predicted to be within the field of view **42** of the star tracker **28** at the plurality of attitudes (block **218**). The plurality of tracked stars **90** may be generated from the tracked star data **62** (e.g., selected from the list of the brightest perceived stars **48***a*).

Referring still to FIG. **11**, as shown at block **224**, whether the plurality of tracked stars **90***a* within the field of view **42** of the star tracker **28** corresponds to the minimum number of star entries **50***a* of the plurality of star entries **50** in the star catalog **34** (e.g., the minimum number of stars **20***a* represented in the star catalog **34** as star entries **50***a*) may be determined. As expressed herein above, the minimum number star entries **50***a* may be based on the minimum number of identified stars **52***a* (e.g., the tracked stars **90***a* having a corresponding star entry **50***a* in the star catalog **34**) required to aid in determining attitude, properly estimate error, and/or aid in maintaining the coarse attitude of the vehicle **12**. Determining whether the plurality of tracked stars **90***a* corresponds to the minimum number of star entries **50***a* (e.g., at least the required minimum number) (block **224**) may include comparing the determined plurality of tracked stars **90** (block **222**) to the plurality of star entries **50** in the star catalog **34** and determining whether the plurality of tracked stars **90** are represented by the minimum number of star entries **50***a* in the star catalog **34** (e.g., representing the plurality of stars **20**).

If the plurality of tracked stars **90** does correspond to the minimum number of star entries **50***a* (e.g., the minimum number of identified stars **52***a* is present), then the dry spot **38** may not occur at the plurality of attitudes **134** (block **218**) and no action may be required or taken to modify the star catalog **34** onboard the vehicle **12** and the operation may end, as shown at block **226**.

If the plurality of tracked stars **90** does not correspond to the minimum number of star entries **50***a* (e.g., the minimum number of identified stars **52***a* is not present), then the location of the occurrence of the dry spot **38** may be determined based on the plurality of attitudes **134** where the plurality of tracked stars **90** does not correspond to the minimum number of star entries **50***a* in the star catalog **34**, as shown at block **292**. Since the dry spot **38** may occur at the determined location (e.g., the plurality of attitudes **134** (block **218**)), action may be required or taken to modify the star catalog **34** onboard the vehicle **12** (block **204**).

In one example implementation, one or more of the steps and/or operations of the disclosed method **200** may include

one or more iterative cycles in order to mitigate the occurrences of dry spots **38** at the determined plurality of attitudes **134** (block **218**) of the vehicle **12**. As one example, upon modification of the star catalog **34** (block **204**), the determination of whether the minimum number of star entries **50***a* correspond to the plurality of tracked stars **90** (block **224**) may be repeated based on the modified plurality of star entries in the modified star catalog (e.g., the combination of star entries **50***a* originally included in the star catalog **34** and the modification star entries **86***a* modifying the star catalog **34**) until the minimum number of star entries **50***a* corresponds to plurality of tracked stars **90** (e.g., until the minimum number of identified stars **52***a* are present) at the plurality of attitudes **134** (block **218**), as illustrated in FIG. **11**.

In one example implementation, one or more of the steps and/or operations of the disclosed method **200** may include one or more iterative cycles in order to mitigate the occurrences of dry spots **38** throughout the attitude history of the vehicle **12**. As one example, the prediction of the occurrence of the dry spot **38** (block **202**) (e.g., the determination of the location of the occurrence of the dry spot (block **206**)) may be repeated for all of attitudes **134** defining the attitude history of the vehicle **12**. For example, the determination of the plurality of attitudes **134** of the vehicle **12** (block **218**) may be repeated for all attitudes and the steps and/or operations illustrated in blocks **220**, **222**, **224**, and **292** may be repeated for all attitudes **134** of the attitude history.

Referring to FIG. **12**, in one embodiment, determining the date of the occurrence of the dry spot **38** (block **208**) may include determining a plurality of attitudes **134** of the vehicle **12**, as shown at block **226**. In one example implementation, the plurality of attitudes **134** of the vehicle **12** may be determined from the attitude data **58**, for example, in substantially the same manner as described herein above (e.g., block **218** of FIG. **11**). The attitude data **58** may include discrete attitude information of the vehicle **12** at each time coordinate of the plurality of time coordinates. The time coordinate may include a date/time set associated with each attitude **134** of the plurality of attitudes **134**.

As shown at block **228**, the star catalog **34**, including the plurality of star entries **50**, may be provided. In one example implementation, the star catalog **34** including the plurality of star entries **50** may be or may be a representation of the star catalog **34** included in the memory **30** of the apparatus **18** of the vehicle **12**. For example, the star catalog **34** may include the plurality of star entries **50** initially selected from the main star database **88**.

As shown at block **230**, the plurality of tracked stars **90** within the field of view **42** of the star tracker **28** of the plurality of attitudes **134** (e.g., at each attitude **134**) may be determined. In one example implementation, the plurality of tracked stars **90** within the field of view **42** of the star tracker **28** of the plurality of attitudes **134** (block **226**) may be determined from the perceived star data **60** and/or the tracked star data **62**, for example, in a substantially similar manner as described herein above (e.g., block **222** of FIG. **11**).

As shown at block **232**, a first (e.g., initial) attitude **134***a* of the plurality of attitudes **134** where the plurality of tracked stars **90** does not correspond to the minimum number of star entries **50***a* in the star catalog **34** may be determined. In one example implementation, the first attitude **134***a* (FIG. **7**) of the plurality of attitudes **134** where the determined plurality of tracked stars **90** (e.g., block **230**) does not correspond to the minimum number of star entries **50***a* may be determined by determining the first attitude **134***a* (and an associated first time coordinate) of a chronological sequence of attitudes where (e.g., at what attitude) or when (e.g., at what time coordinate) the plurality of tracked stars **90** does not correspond to the minimum number of star entries **50***s* does not correspond to the plurality of tracked stars **90**. The minimum number of star entries **50***a* required may be based on the minimum number of identified stars **52***a* (e.g., the tracked stars **90***a* having a corresponding star entry **50***a* in the star catalog **34**) required to properly estimate error and/or aid in maintaining the coarse attitude of the vehicle **12**. Determining whether the plurality of tracked stars **90** corresponds to the minimum number of star entries **50***s* may include comparing the plurality of tracked stars **90** to the plurality of star entries **50** in the star catalog **34** and determining if a required minimum number of tracked stars **90***a* (e.g., the minimum number of identified stars **52***a*) corresponds to the minimum number of star entries **50***a* in the star catalog **34**, for example, in a substantially similar manner as described herein above (e.g., block **224** of FIG. **11**).

As shown at block **286**, the date of the occurrence of the dry spot **38** may be determined based on a first time coordinate (e.g., a date/time set) of the first attitude **134***a*. As one example, the first time coordinate associated with the first attitude **134***a* of the chronological sequence of attitudes **134** may define the date/time of the occurrence of the dry spot **38**.

Referring to FIG. **13**, in one embodiment, determining the duration of the occurrence of the dry spot **38** (block **210**) may include determining the plurality of attitudes **134** of the vehicle **12**, as shown at block **234**. In one example implementation, the plurality of attitudes **134** of the vehicle **12** may be determined from the attitude data **58**, for example, in substantially the same manner as described herein above (e.g., block **218** of FIG. **11**). The attitude data **58** may include discrete attitude information of the vehicle **12** at each time coordinate of the plurality of time coordinates. The time coordinate may include the date/time set associated with each attitude **134** of the plurality of attitudes **134**.

As shown at block **236**, the star catalog **34**, including the plurality of star entries **50**, may be provided. In one example implementation, the star catalog **34** including the plurality of star entries **50** may be or may be a representation of the star catalog **34** included in the memory **30** of the apparatus **18** of the vehicle **12**. For example, the star catalog **34** may include the plurality of star entries **50** initially selected from the main star database **88**.

As shown at block **238**, the plurality of tracked stars **90** within the field of view **42** of the star tracker **28** at the plurality of attitudes **134** (e.g., at each attitude) may be provided. In one example implementation, the plurality of tracked stars **90** within the field of view **42** of the star tracker **28** at the plurality of attitudes **134** (e.g., at each attitude) may be determined from the perceived star data **60** and/or the tracked star data **62**, for example, in a substantially similar manner as described herein above (e.g., block **222** of FIG. **11**).

As shown at block **240**, a first (e.g., starting) attitude **134***a* (FIG. **7**) of the plurality of attitudes **134** where the determined plurality of tracked stars (block **238**) does not correspond to the minimum number of star entries **50***a* (e.g., at least the required minimum number) may be determined. In one example implementation, the first attitude **134***a* of the plurality of attitudes **134** where the plurality of tracked stars **90** does not correspond to the minimum number of star entries **50***a* (block **240**) may be determined by determining the first attitude **134***a* (and an associated first time coordinate) of a chronological sequence of attitudes where (e.g., at

what attitude) or when (e.g., at what time coordinate) the plurality of tracked stars **90** does not correspond to the minimum number of star entries **50***a*, for example, in a substantially similar manner as described herein above (e.g., block **232** of FIG. **12**). The minimum number of star entries **50***a* may be based on the minimum number of identified stars **52***a* (e.g., the tracked stars **90***a* having a corresponding star entry **50***a* in the star catalog **34**) required to properly estimate error and/or aid in maintaining the coarse attitude of the vehicle **12**. Determining whether the plurality of star entries **90** corresponds to the minimum number of star entries **50***a* may include comparing the plurality of tracked stars **90** to the plurality of star entries **50** in the star catalog **34** and determining if the plurality of tracked stars **90** corresponds to the minimum number of star entries **50***a* (e.g., at least the required minimum number of star entries **50***a*), for example, in a substantially similar manner as described herein above (e.g., block **224** of FIG. **11**). The time coordinate associated with the first attitude **134***a* of the chronological sequence of attitudes **134** may define the start of the occurrence of the dry spot **38**.

As shown at block **242**, a second (e.g., ending) attitude **134***b* (FIG. **7**) of the plurality of attitudes **134** where the plurality of tracked stars **90** does correspond to the minimum number of star entries **50***a* (e.g., at least the required minimum number) may be determined. The second attitude **134***b* may occur after the first attitude **134***a*. In one example implementation, the second attitude **134***b* of the plurality of attitudes **134** where the plurality of tracked stars **90** does correspond to the minimum number of star entries **50***a* (block **242**) may be determined by determining the second attitude **134***b* (and associated second time coordinate) of a chronological sequence of attitudes **134** where (e.g., at what attitude) or when (e.g., at what time coordinate) the plurality of tracked stars **90** correspond to the minimum number of star entries **50***a*.

The minimum number of star entries **50***a* may be based on the minimum number of identified stars **52***a* (e.g., the tracked stars **90***a* having a corresponding star entry **50***a* in the star catalog **34**) required to properly estimate error and/or aid in maintaining the coarse attitude of the vehicle **12**. Determining whether the plurality of tracked stars **90** corresponds to the minimum number of star entries **50** (e.g., at least the minimum number of star entries **50***a*) may include comparing the plurality of tracked stars **90** to the plurality of star entries **50** in the star catalog **34** and determining if the plurality of tracked stars **90** corresponds to the minimum number of star entries **50***a*, for example, in a substantially similar manner as described herein above (e.g., block **224** of FIG. **11**). The second time coordinate associated with the second attitude **134***b* of the chronological sequence of attitudes **134** may define the end of the occurrence of the dry spot **38**.

As shown at block **288**, a time period **136** (FIG. **7**) between the first time coordinate of the first attitude **134***a* and the second time coordinate of the second attitude **134***b* may be determined. As one example, the duration of time between the first time coordinate (e.g., at the first attitude **134***a*) and the second time coordinate (e.g., at the second attitude **134***b*) may define the time period **136**.

As shown at block **290**, the duration of the occurrence of the dry spot **38** may be determined based on the time period **136**. As one example, the time period **136** between the first time coordinate (e.g., at the first attitude **134***a*) and the second time coordinate (e.g., at the second attitude **134***b*) may define the duration of the occurrence of the dry spot **38**.

Referring to FIG. **9**, those skilled in the art will recognize that the steps and/or operations shown at blocks **206**, **208**, and **210** may occur substantially concurrently (e.g., at the same time) or may occur separately (e.g., at different times).

Referring to FIG. **14**, in one embodiment, generating the proposed set of modifications **36** to modify the star catalog **34** (block **212**) may include determining a plurality of attitudes **134** of the vehicle **12**, as shown at block **294**. In one example implementation, the plurality of attitudes **134** of the vehicle **12** may be determined from the attitude data **58**, for example, in substantially the same manner as described herein above (e.g., block **218** of FIG. **11**).

As shown at block **296**, the star catalog **34**, including the plurality of star entries **50**, may be provided. In one example implementation, the star catalog **34** including the plurality of star entries **50** may be or may be a representation of the star catalog **34** included in the memory **30** of the apparatus **18** of the vehicle **12**. For example, the star catalog **34** may include the plurality of star entries **50** initially selected from the main star database **88**.

As shown at block **298**, the plurality of tracked stars **90** within the field of view **42** of the star tracker **28** at the plurality of attitudes **134** (e.g., at each attitude) may be determined. In one example implementation, the plurality of tracked stars **90** within the field of view **42** of the star tracker **28** at the plurality of attitudes **134** (e.g., at each attitude) may be determined from the perceived star data **60** and/or the tracked star data **62**, for example, in a substantially similar manner as described herein above (e.g., block **222** of FIG. **11**).

As shown at block **300**, whether the plurality of tracked stars **90** corresponds to the minimum number of star entries **50***a* may be determined. The minimum number of star entries **50***a* required may be based on the minimum number of identified stars **52***a* (e.g., the tracked stars **90***a* having a corresponding star entry **50***a* in the star catalog **34**) required to properly estimate error and/or aid in maintaining the coarse attitude of the vehicle **12**. In one example implementation, determining whether the plurality of tracked stars **90** corresponds to the minimum number of star entries **50***a* may include comparing the plurality of tracked stars **90** to the plurality of star entries **50** in the star catalog **34** and determining if the plurality of tracked stars **90** corresponds to the minimum number of star entries **50***a*, for example, in a substantially similar manner as described herein above (e.g., block **224** of FIG. **11**).

As shown at block **302**, a tracked star **90***a* of the plurality of tracked stars **90** that does not correspond to a star entry **50***a* of the plurality of star entries **50** in the star catalog **34** may be determined. As one example, at least one tracked star **90***a* of the plurality of tracked stars **90** that does not correspond to a star entry **50***a* of the plurality of star entries **50** in the star catalog **34** may be determined. As one example, a set of tracked stars **90***a* of the plurality of tracked stars **90** that do not correspond to a star entry **50***a* of the plurality of star entries **50** in the star catalog **34** may be determined.

In one example implementation, the tracked star **90***a* that does not have a corresponding star entry **50***a* in the star catalog **34** may be determined by comparing a tracked star **90** (e.g., from the plurality of tracked stars **90** determined by the step and/or operation shown at block **298**) to the plurality of star entries **50** (e.g., the plurality of star entries **50** in the star catalog **34** provided by the step and/or operation shown at block **296**), determining if tracked star **90***a* has a corresponding star entry **50***a* in the star catalog **34**, and identi-

fying the tracked star **90***a* as not have a corresponding star entry **50***a* in the star catalog **34** (e.g., is not identified star **52***a*).

As shown at block **304**, a modification star entry **86***a* corresponding to the tracked star **90***a* that does not correspond to a star entry **50***a* of the plurality of star entries **50** in the star catalog **34** may be determined. As used herein, the modification star entry **86***a* may be a star entry **50***a* from the main star database **88** that is currently not in the star catalog **34**. As one example, at least one modification star entry **86***a* corresponding to at least one tracked star **90** that does not correspond to a star entry **50***a* may be determined. As one example, a set of modification star entries **86***a* corresponding to a set of tracked stars **90***a* that do not correspond to a star entry **50***a* may be determined.

In one example implementation, determining the modification star entry **86***a* corresponding to the tracked star **90***a* that does not correspond to a star entry **50***a* in the star catalog **34** (block **304**) may include comparing the tracked star **90***a* to the plurality of star entries **50** in the main star database **88**, determining whether the main star database **88** includes a star entry **50***a* corresponding to the tracked star **90***a* that does not have a corresponding star entry **50***a* in the star catalog **34**, and selecting the star entry **50***a* corresponding to the tracked star **90***a* from the main star database **88** to be the modification star entry **86***a* (e.g., a candidate modification star entry).

If the main star database **88** does not include a star entry **50***a* corresponding to the tracked star **90***a* that does not correspond to a star entry **50***a* in the star catalog **34**, then the tracked star **90***a* may be identified and/or documents as an unidentifiable star and another tracked star **90***a* that does not correspond to a star entry **50***a* in the star catalog **34** may be determined (e.g., block **302**) and the step and/or operation shown at block **304** may be repeated until a suitable modification star entry **86***a* is found. If the number of suitable modification star entries **86***a* (e.g., defining the set of modifications **36**) does not provide the minimum number of identified stars **52***a* (e.g., the minimum number of star entries **50***a* and modification star entries **86***a* do not correspond to the plurality of tracked stars **90**), then the dry spot **38** may be identified and/or documented as an unfixable dry spot.

As shown at block **306**, whether the modification star entry **86***a* can modify the star catalog **34** may be determined. As one example, determining whether the modification star entry **86***a* can modify the star catalog **34** may depend on whether the corresponding tracked star **90***a* is a suitably identifiable star **20***a*. As one example, determining whether the modification star entry **86***a* can modify the star catalog **34** may depend on whether the modification star entry **86***a* is a viable modification to the star catalog **34**. As one example, determining whether the modification star entry **86***a* can modify the star catalog **34** may depend on whether one or more star entries **50***a* in the star catalog **34** may be removed and/or replaced.

Referring to FIG. **15**, in one embodiment, determining whether the modification star entry **86***a* can modify the star catalog **34** (block **306**) may include determining whether the modification star entry **86***a* (e.g., the tracked star **90***a*) includes an (e.g., one or more) exclusionary property **144** (FIG. **8**), as shown at block **308**. The exclusionary property **144** may include any star property, characteristic, and/or metric that make the modification star entry **86***a* unsuitable and/or undesirable to modify the star catalog **34**. For example, exclusionary properties **144** may include, but are not limited to, if a star **20***a* moves with respect to a celestial sphere at a relatively high rate (e.g., the position of the star **20***a* changes fast enough to potentially cause problems with attitude determination); if the star **20***a* (e.g., target star) has a near neighbor (e.g., another star **20***a* that is nearby or appears nearby when viewed from Earth) that may be mistaken for the target star; if the star **20***a* has a magnitude that varies widely over time, making the star **20***a* difficult to identify; and the like.

As shown at block **310**, if the modification star entry **86***a* includes the exclusionary property **144**, then the modification star entry **86***a* may be excluded from modifying the star catalog **34**. As shown at block **312**, if the modification star entry **86***a* does not include the exclusionary property, then the modification star entry **86***a* may be recommended for modifying the star catalog **34**.

In one example implementation, the set of modifications **36** (e.g., one or more modification star entries **86***a*) may be added to the star catalog **34** without replacing any of the existing star entries **50***a* in the star catalog **34**. In one example implementation, the set of modifications **36** (e.g., one or more modification star entries **86***a*) may replace one or more existing star entries **50***a* in the star catalog **34** (e.g., the existing star entries **50***a* may be removed from the star catalog **34**).

Referring to FIG. **16**, in one embodiment (e.g., in the case where one or more star entries **50***a* are replaced by one or more modification star entries **86***a*), determining whether the modification star entry **86***a* can modify the star catalog **34** (block **306**) may include determining whether the star entry **50***a* (e.g., one or more existing star entries) in the star catalog **34** is replaceable, as shown at block **316**.

In one example implementation, determining whether the star entry **50***a* in the star catalog **34** is replaceable (block **316**) may include determining whether the star entry **50***a* meets one or more replacement criteria. A variety of replacement criteria may determine whether the star entry **50***a* in the star catalog **34** is a replaceable star entry **50***a*. As one example, the replacement criteria may require that the star entry **50***a* to be replaced cannot be associated with another star entry **50***a* in the star catalog **34** (e.g., is not paired to another star entry **50***a* in the star catalog index). As one example, the replacement criteria may require that the star entry **50***a* to be replaced have a brightness value **100** (e.g., a brightness) less than the modification star entry **86***a*. For example, a star entry **50***a* of the star catalog **34** may only be replaced by a modification star entry **86***a* having a greater brightness value **100**.

If the star entry **50***a* in the star catalog **34** is not replaceable, then another (e.g., different) tracked star **90***a* that does not correspond to a star entry **50***a* in the star catalog **34** may be determined (e.g., block **302**) and the step and/or operation shown at blocks **304** and **306** may be repeated until a suitable modification star entry **86***a* and a suitably replaceable star entry **50***a* is found. If the number of replaceable star entries **50***a* does not allow for a suitable number of modification star entries **86***a* (e.g., defining the set of modifications **36**) to be added to the star catalog **34** in order to provide the minimum number of identified stars **52***a* (e.g., the minimum number of star entries **50***a* and modification star entries **86***a* do not correspond to the plurality of tracked stars **90**), then the dry spot **38** may be identified and/or documented as an unfixable dry spot, as shown at block **318**.

If the star entry **50***a* in the star catalog **34** is replaceable, then whether the modification star entry **86***a* (e.g., the candidate star entry **50***a* selected from the main star database **88**) is a viable modification to the star catalog **34** may be determined, as shown at block **320**. In one example imple-

mentation, determining whether the modified star entry **86***a* is a viable modification to the star catalog **34** (block **320**) may include determining whether the modification star entry **86***a* meets replacement criteria. A variety of replacement criteria may determine whether the modified star entry **86***a* is a viable modification to the star catalog **34**.

As one example, the replacement criteria may require that the modification star entry **86***a* have a predetermined proper motion (e.g., the proper motion is less than 0.5 arc-sec/year). As one example, the replacement criteria may require that the modification star entry **86***a* not represent a tracked star **90***a* that is within a predetermined distance from another tracked star **90***a* having a brightness value **100** sufficiently appreciable that the star tracker **28** is likely to track (e.g., the modification star entry **86***a* cannot represent a tracked star **90***a* that is too close to another bright tracked star **90***a*). Those skilled in the art will recognize that the predetermined distance between bright tracked stars **90***a* may depend on the type of star tracker **28** and/or the type of vehicle **12**.

If the modification star entry **86***a* is not a viable modification to the star catalog **34**, then another (e.g., different) tracked star **90***a* that does not correspond to a star entry **50***a* in the star catalog **34** may be determined (e.g., block **302**) and the step and/or operation shown at blocks **316** and **320** may be repeated until a suitable modification star entry **86***a*, a suitably replaceable star entry **50***a*, and a viable modification star entry **86***a* is found. If the number of viable modification star entries **86***a* does not to provide the minimum number of identified stars **52***a* (e.g., the minimum number of star entries **50***a* and modification star entries **86***a* do not correspond to the plurality of tracked stars **90**), then the dry spot **38** may be identified and/or documented as an unfixable dry spot (block **318**).

If the modification star entry **86***a* is a viable modification to the star catalog **34**, then the modification star entry may be recommended as a modification to the star catalog, as shown at block **322**.

If the star entry **50***a* in the star catalog **34** are replaceable, then the modification star entry **86***a* may be recommended (block **262**) and selected for inclusion to the star catalog **34** (block **254**).

Referring to FIGS. **14-16**, the modification star entry **86***a* may be included to the set of modifications **36** when recommended (block **312** and/or block **322**), as shown at block **314**. As one example, a plurality of recommended modification star entries **86** may be included to the set of modifications **36**. In one example implementation, one or more of the steps and/or operations described for generating the set of modifications **36** to modify the star catalog **34** (block **212**) may be repeated to select and add a plurality of modification star entries **86** sufficient to represent the minimum number of identified stars **52***a* (e.g., the minimum number of star entries **50***a* and modification star entries **86***a* in the star catalog **34** correspond to the plurality of tracked stars **90**) required to properly estimate error and/or aid in maintaining the coarse attitude of the vehicle **12** (e.g., mitigate the occurrences of dry spots **38** throughout the attitude history of the vehicle **12**).

Referring to FIG. **17**, in one embodiment, generating the modification schedule **68** for modifying the star catalog **34** with the set of modifications **36** (block **214**) may include determining a date/time for uploading the set of modifications **36** to the star catalog **34**, as shown at block **264**.

In one example implementation, determining the date/time for uploading the set of modifications **36** to the star catalog **34** (block **264**) may include determining the first time coordinate (e.g., at the first attitude **134***a*) where the plurality of tracked stars **90** does not correspond to the minimum number of star entries **50***a*, as shown at block **266**. As one example, the plurality of tracked stars **90** may be determined in a substantially similar manner as described herein above, for example, as shown at block **230** of FIG. **12**. As one example, the first time coordinate where the plurality of tracked stars **90** does not correspond to the minimum number of star entries **50***a* may be determined in a substantially similar manner as described herein above, for example, as shown at block **232** of FIG. **12**. As one example, determining the first time coordinate where the plurality of tracked stars **90** does not correspond to the minimum number of star entries **50***a* may include at least one of determining the date of the occurrence of the dry spot **38** (block **208** of FIGS. **9** and **12**) or determining the duration of the occurrence of the dry spot **38** (block **210** of FIGS. **9** and **13**).

As shown at block **268**, a second time coordinate (e.g., a date/time set) may be determined prior to the first time coordinate. As an example, the second time coordinate may include an associated second attitude **134***c* (FIG. **7**) occurring before the first attitude **134***a*.

As shown at block **270**, whether the second time coordinate meets modification constraints may be determined. Those skilled in the art will recognize that multiple modification constraints may be applied to the determination of the second time coordinate. As one example, the modification constraint may include only date/times where the set of modifications **36** being uploaded to the star catalog **34** do not alter the star entries **50***a* in the star catalog **34** corresponding to the plurality of tracked stars **90** being tracked at that time coordinate (e.g., attitude). As one example, the determined date/time may be the time coordinate when the star entries **50***a* being changed (e.g., removed and/or replaced) by the modification star entries **86***a* are not being used to identify the plurality of tracked stars **90** being tracked by the star tracker **28** at that time coordinate.

If the second time coordinate does not meet the modification constraints (block **270**), then another (e.g., different) second time coordinate prior to the first time coordinate may be determined (e.g., block **268**).

If the second time coordinate does meet the modification constraints (block **270**), then the second time coordinate may be recommended as the date/time for uploading the set of modifications **36** to the star catalog **34**, as shown at block **272**.

As shown at block **274**, the date/time (e.g., the second time coordinate) to upload the set of modifications **36** to the star catalog **34** may be added to the modification schedule **68**. In one example implementation, the date/time may be recommended prior to the vehicle **12** attaining the attitude where the minimum number of star entries **50***s* do not correspond to the plurality of tracked stars **90***a* (e.g., the first attitude **134***a*) and when date/time meets the modification constraints (e.g., when the set of modifications **36** will not change star entries **50***a* being used at that date/time). As one example, the modification schedule **68** may include a plurality of date/times for modifying the star catalog **34** based on the number of dry spots **38**, the location of the dry spots **38** and/or the duration of the dry spots **38**.

As the disclosed method **200** may be iterative, a new (e.g., refreshed) visualization **84** may be generated (block **244**) after each iteration (e.g., of the steps and/or operations shown at blocks **202** and **204**) in order to provide an updated visualization **84** of the occurrence of one or more dry spots

38 at the plurality of attitudes 134 of the vehicle 12 accounting for the modification star entries 86*a* modifying the star catalog 34.

As one example, the steps and/or operations of the disclosed method 200 may be repeated as many times as needed to obtain the minimum number of star entries 50*a* (e.g., the existing star entries 50*a* of the star catalog 34 and the modification star entries 86*a* modifying the star catalog 34) corresponding to the plurality of tracked stars 90 (e.g., the minimum number of identified stars 52*a*) required to properly estimate error and/or aid in maintaining an attitude estimate of the required accuracy of the vehicle 12.

Each modification star entry 86*a* (e.g., the star entry 50*a* selected from the main star database 88 based upon the steps and/or operations described herein above) may include the star data 82. The star data 82 may include a recorded value 66 of at least one metric 66 of the corresponding star 20*a* of the plurality of stars 20. As one example, the modification star entry 86*a* may include a plurality of metrics 70. The plurality of metrics 70 may include at least one of: a right ascension angle 72 of the star 62 in a given ECI coordinate frame 22, a declination angle 74 of the star 62 in the given ECI coordinate frame 22, a magnitude 76 of the star 62, a star vector 78, identification number 80 of the star 62 and/or other metrics 70 (e.g., properties) of the star 62. For example, the value 66 of the magnitude 76 may be the brightness value 100 of the star 62.

Referring to FIG. 18, in one embodiment predicting the occurrence of the dry spot 38 (block 202) may include predicting the tracked stars 90 within the field of view 42 of the star tracker 28 at the plurality of attitudes 130, as shown at block 344. Those skilled in the art will recognize that which star 20*a* the star tracker 28 locks onto and tracks (e.g., tracked star 90*a*) may depend upon the star magnitude 76 (e.g., brightness value 100) of the star 20*a*. As one example, the star tracker 28 may use the magnitude 76 of the star 20*a* to determine which stars 20*a* to track (e.g., which of the perceived stars 48*a* within the field of view 42 will be tracked stars 90*a*). Therefore, accurate and/or updated star magnitude estimates may be needed in order to predict the occurrence to the dry spot 38.

As one example, measured magnitudes from multiple different star trackers (e.g., star trackers made by different manufacturers) may be used to provide accurate star magnitude estimates. The additional star magnitude data may result in increased accuracy of dry spot prediction (e.g., date and/or duration determination) by aiding in the determination of which stars 20*a* the star tracker 28 is likely to track (e.g., the brightest stars). The occurrence of the dry spot 38 may depend on the star magnitude and/or the accuracy of the star magnitude data.

Those skilled in the art will recognize that there are vast amounts of star magnitude data is available (e.g., on the Internet, in astronomical databases, and based on satellite observations). However, different devices (e.g., different star trackers and/or vehicles) may provide different values for the recorded magnitudes. This may be true even for magnitude readings of the same star taken at the same time. Accordingly, the large amounts of magnitude data recorded by different types of star trackers may need to be adjusted for use with the star tracker of interest (e.g., measured magnitudes may need to be converted (e.g., mapped) to equivalent magnitudes for the star tracker 28).

Thus, the present disclosure recognizes and takes into account the benefit of being able to use magnitude data (e.g., values) for stars taken from many star trackers and/or many different types of star trackers.

As shown at block 346, a plurality of perceived stars 48 within the field of view 42 of the star tracker 28 may be determined. As shown at block 348, the plurality of perceived stars 48 within the field of view 42 may be ranked based on the magnitude value 66 of the star 20*a*.

As shown at block 330, first magnitude values of a first plurality of stars may be provided. The first magnitude values may include magnitude values of the first plurality of stars provided from (e.g., recorded by) the first star tracker. The first plurality of stars may include a large series (e.g., a large number) of stars. As one example, the first magnitude value may be a recorded magnitude value of a star taken (e.g., reported) by the first star tracker or a plurality of first star trackers.

As shown at block 332, second magnitude values of a second plurality of stars may be provided. The second magnitude values may include magnitude values of the second plurality of stars provided from (e.g., recorded by) a second star tracker (e.g., the star tracker 28). The second plurality of stars may be a sub-set of (e.g., included in) the first plurality of stars (e.g., a smaller series of stars). As one example, at least some of the stars in the first and second plurality of stars are the same. The second magnitude value may be an equivalent magnitude value if the magnitude value for the same star was taken by the second star tracker. As one example, the second star tracker may be the star tracker 28 and the first star tracker (or plurality of first star trackers) may be a type of star tracker than is different from the star tracker 28.

In one example implementation, star magnitude data may be recorded and/or gathered from a vehicle 12 (e.g., a spacecraft) using star tracker X (e.g., the second star tracker that is the same as the star tracker 28). Star magnitude data may be recorded and/or gathered from one or more vehicles 12 (e.g., a spacecraft) using star tracker Y (e.g., various different types of first star trackers). Star tracker X and star tracker Y may be different types of star trackers. A large amount of star magnitude data may result from recorded data taken from more than one star tracker Y.

The star magnitude data taken from both star tracker X and star tracker Y may be compared to find star magnitude for common stars (e.g., non-variable stars) or a common sets of stars. The common set of stars may be used to calculate a mapping function such that given a magnitude (e.g., value) for a star reported by star tracker Y, an equivalent magnitude that would be reported for the same star by star tracker X may be determined (e.g., converting the magnitude from star tracker Y to the magnitude for star tracker X).

As shown at block 334, a converter may be generated based on a relationship (e.g., a mathematical relationship) between the first magnitude values and the second magnitude values (e.g., mapping). As one example, the converter may be linear formula configured to convert the first magnitude value to the second magnitude value.

As shown at block 336, the first magnitude values of the first plurality of stars may be converted, by the converter, to the second magnitude values of the first plurality of stars.

As shown at block 350, the plurality of perceived stars 48 may be re-ranked based on the second magnitude values.

As shown at block 244, the plurality of tracked stars 90 (e.g., the plurality of perceived stars 48 within the field of view 42 of the star tracker 28 that will be tracked by the star tracker 28) may be predicted based on the re-ranked plurality of perceived stars 48 (e.g., based on the updated second magnitude values). Those skilled in the art will recognize that a star tracker will lock onto and track a predetermined number (e.g., a minimum number) of stars 20*a* within the

field of view **42**. Thus, an assumption may be made that the brightest stars **20***a* within the field of view **42** may define the predetermined number of tracked stars **90***a*. The brightest perceived stars **48***a* based on the second magnitude values may represent the predetermined number of tracked stars **90***a*.

As one example, if the star tracker **28** is designed to track eight stars, then the eight brightest stars within the field of view **42** at the corresponding attitude **130** are the stars most likely to be tracked. Thus, the top eight brightest perceived stars **48***a* based on the re-ranking of the perceived stars **48***a* may represent the tracked stars **90***a*.

In one example implementation, the steps and/or operations described above (e.g., blocks **346**, **348**, **330**, **332**, **334**, **336**, **350**, and **344**) may be used to determine the plurality of tracked stars **90** as described herein, for example at blocks **222**, **230**, **238**, and **298**.

Referring to FIG. **14**, in one embodiment, generating the set of modifications **36** to modify the star catalog **34** (block **212**) may include modifying one or more of the modification star entries **86***a*, as shown at block **326**.

In one example implementation, modifying the star entry **86***a* (block **326**) may include converting the first magnitude value taken from the first star tracker to the second magnitude value for the second star tracker. Converting the first magnitude value taken from the first star tracker to the second magnitude value for the second star tracker may be performed in a substantially similar manner as described herein above and shown at blocks **330**, **332**, **334**, and **336**.

The modification star entries **86***a* (e.g., the star data **82** of the modification star entries **86***a*) may be modified to include the second magnitude values for the corresponding stars for use by the star tracker **28**.

Those skilled in the art will recognize that the steps and/or operations shown at blocks **326**, **328**, **330**, **332**, **334**, and **336** may also be performed to modify the star entries **50***a* initially selected for inclusion in the star catalog **34** and used in connection with the star tracker **28**.

In one example implementation, the star data **82** of the modification star entry **86***a* may be updated based upon one or more observed metrics **70***a*. As one example, the recorded value **66** of one or more metrics **70***a* of the star data **82** of the modification star entry **86***a* (e.g., the star entry **50***a* selected from the main star database **88**) may not properly and/or accurately represent the actual value **66** of the metric **70***a* of the star **20***a*. As one example, the observed (e.g., actual) brightness value **100** (e.g., value **66**) of the magnitude **76** (e.g., metric **70***a*) of the star **20***a* may be greater than or less than the recorded brightness value **100** of the star **20***a*. As one example, the magnitude of certain stars **20***a* may vary over time.

Thus, in order to determine whether the modification star entry **86***a* is a viable modification to the star catalog **34** (block **320** of FIG. **16**), the recorded magnitude and the observed magnitude may be compared. As one example, the recorded magnitude may be changed to the observed magnitude if at least one of: a maximum brightness value of the observed magnitude is greater than a maximums brightness value of the recorded magnitude; or a minimum brightness value of the observed magnitude is less than a minimum brightness value of the recorded magnitude. As one example, a specific recorded magnitude (e.g., brightness value) may be set based on a range of observed magnitudes (e.g., the magnitude **76** may be chosen to be within a predetermined threshold or tolerance of all of the observed magnitudes for the star **20***a* during the period of time when the star **20***a* is tracked by the star tracker **28**).

Thus, the steps and/or operations described above may ensure that the modification star entry **86***a* includes accurate star data **82** (e.g., accurate magnitude values) and the maximum known or estimated brightness value **100**.

Referring to FIG. **10**, in one example embodiment, uploading the set of modifications **36** to the star catalog **34** (block **216**) may include storing at least one modification star entry **86***a* of the plurality of modification star entries **86** to the set of modifications **36**; storing the set of modifications **36**; and transmitting the set of modifications **36** to the star catalog **34**. As one example, the set of modifications **36** may be transmitted to the star catalog **34** and stored in the memory **32** of the apparatus **18** of the vehicle **12** (e.g., uploaded to the vehicle **12**), for example, at the date/time recommended by the modification schedule **68**. As one example, the set of modifications **36** may be stored in remote memory (not shown), for example at the station **14** on the Earth **16**, and transmitted to the vehicle **12** (e.g., uploaded to the vehicle **12**), for example, at the date/time recommended by the modification schedule **68**.

Although various embodiments of the disclosed system and method have been shown and described, modifications may occur to those skilled in the art upon reading the specification. The present application includes such modifications and is limited only by the scope of the claims.

What is claimed is:

1. A method implemented by a computing device for mitigating an occurrence of a dry spot, said method comprising:

predicting said occurrence of said dry spot at a plurality of attitudes, said dry spot occurring when a star tracker cannot identify a minimum number of tracked stars within a field of view because at least one of said minimum number of tracked stars does not have a corresponding star entry in a star catalog;

determining whether said dry spot will impact attitude determination performance based on whether said minimum number of tracked stars predicted to be within said field of view are identifiable by corresponding star entries in said star catalog at said plurality of attitudes; and

modifying a said star catalog to reduce impact on said attitude determination performance due to said dry spot by including at least one modification star entry to said star catalog corresponding to said at least one of said minimum number of tracked stars that does not have said corresponding star entry in said star catalog.

2. The method of claim **1** further comprising generating a visualization of said occurrence of said dry spot.

3. The method of claim **2** wherein generating said visualization of said occurrence of said dry spot comprises:

generating a plot comprising a plurality of points of right ascensions and declinations to which a boresight of said star tracker points;

determining whether a plurality of tracked stars within said field of view of said star tracker corresponds to a minimum number of star entries in said star catalog at each point of said plurality of points;

coding said each point based upon a determination of whether said minimum number of star entries in said star catalog corresponds to said plurality of tracked stars;

generating a visual representation of said dry spot based upon said coding of said each point; and

generating a visual representation of a trajectory of said boresight.

4. The method of claim 1 wherein predicting said occurrence of said dry spot comprises at least one of:

determining a location of said occurrence of said dry spot;

determining a date of said occurrence of said dry spot; and

determining a duration of said occurrence of said dry spot.

5. The method of claim 4 wherein determining said location of said occurrence of said dry spot comprises:

determining said plurality of attitudes of a vehicle;

providing said star catalog, said star catalog comprising a plurality of star entries;

determining a plurality of tracked stars within said field of view of said star tracker at said plurality of attitudes;

determining whether said plurality of tracked stars corresponds to a minimum number of star entries; and

determining said location of said occurrence of said dry spot based on said plurality of attitudes where said plurality of tracked stars does not correspond to said minimum number of star entries.

6. The method of claim 4 wherein determining said date of said occurrence of said dry spot comprises:

determining said plurality of attitudes of a vehicle;

providing said star catalog, said star catalog comprising a plurality of star entries;

determining a plurality of tracked stars within said field of view of said star tracker at said plurality of attitudes;

determining a first attitude of said plurality of attitudes where said plurality of tracked stars does not correspond to a minimum number of star entries; and

determining said date of occurrence of said dry spot based on a first time coordinate of said first attitude.

7. The method of claim 4 wherein determining said duration of said occurrence of said dry spot comprises:

determining said plurality of attitudes of a vehicle;

providing said star catalog, said star catalog comprising a plurality of star entries;

determining a plurality of tracked stars within said field of view of said star tracker at said plurality of attitudes;

determining a first attitude of said plurality of attitudes where said plurality of tracked stars does not correspond to a minimum number of star entries;

determining a second attitude of said plurality of attitudes where said plurality of tracked stars does correspond to said minimum number of star entries does, said second attitude occurring after said first attitude;

determining a time period between a first time coordinate of said first attitude and a second time coordinate of said second attitude; and

determining said duration of said occurrence of said dry spot based on said time period.

8. The method of claim 1 wherein modifying said star catalog comprises at least one of:

generating a set of modifications to modify said star catalog;

generating a modification schedule for modifying said star catalog; and

uploading said set of modifications to said star catalog.

9. The method of claim 8 wherein generating said set of modifications to modify said star catalog comprises:

determining said plurality of attitudes of a vehicle;

providing said star catalog, said star catalog comprising a plurality of star entries;

determining a plurality of tracked stars within said field of view of said star tracker at said plurality of attitudes;

determining whether said plurality of tracked stars corresponds to a minimum number of star entries;

determining a tracked star of said plurality of tracked stars that does not correspond to a star entry of said plurality of star entries;

determining a modification star entry corresponding to said tracked star;

determining whether said modification star entry can modify said star catalog; and

including said modification star entry to said set of modifications.

10. The method of claim 9 wherein determining whether said modification star entry can modify said star catalog comprises:

determining whether said modification star entry comprises an exclusionary property;

excluding said modification star entry when said modification star entry comprises said exclusionary property; and

recommending said modification star entry when said modification star entry does not comprise said exclusionary property.

11. The method of claim 9 wherein determining whether said modification star entry can modify said star catalog comprises:

determining whether at least one star entry of said plurality of star entries is replaceable;

determining whether said modification star entry is a viable modification to said star catalog; and

recommending said modification star entry when said star entry is replaceable and is said viable modification.

12. The method of claim 8 wherein generating said modification schedule for modifying said star catalog comprises:

determining a first time coordinate where a plurality of tracked stars does not correspond to a minimum number of star entries;

determining a second time coordinate prior to said first time coordinate;

determining whether said second time coordinate meets modification constraints; and

recommending said second time coordinate as a date/time to upload said set of modifications to said star catalog when said second time coordinate meets said modification constraints.

13. The method of claim 1 wherein predicting said occurrence of said dry spot further comprises:

providing first magnitude values of a first plurality of stars;

providing second magnitude values of a second plurality of stars, said second plurality of stars being a sub-set of said first plurality of stars;

converting said first magnitude values of said first plurality of stars to said second magnitude values of said first plurality of stars; and

predicting a plurality of tracked stars within said field of view of said star tracker based on said second magnitude values.

14. The method of claim 1 wherein at least one of predicting said occurrence of said dry spot and modifying said star catalog comprises providing said plurality of attitudes of a vehicle, wherein providing said plurality of attitudes comprises:

providing first attitude data comprising a plurality of first time coordinates and an associated plurality of first attitudes;

providing a regular time duration; and

generating second attitude data comprising a plurality of second time coordinates and an associate plurality of

second attitudes, said plurality of second time coordinates being spaced apart by said regular time duration.

15. A system for mitigating an occurrence of a dry spot, said system comprising:

at least one computing device; and

a non-transitory medium storing instructions that, when executed by said at least one computing device, causes said at least one computing device to:

predict said occurrence of said dry spot at a plurality of attitudes, said dry spot occurring when a star tracker cannot identify a minimum number of tracked stars within a field of view because at least one of said minimum number of tracked stars does not have a corresponding star entry in a star catalog;

determine whether said dry spot will impact attitude determination performance based on whether said minimum number of tracked stars predicted to be within said field of view are identifiable by corresponding star entries in said star catalog at said plurality of attitudes; and

modify said star catalog to reduce an impact of said dry spot by including at least one modification star entry to said star catalog corresponding to said at least one of said minimum number of tracked stars that does not have said corresponding star entry in said star catalog.

16. The system of claim **15** wherein said instructions, when executed by said at least one computing device, further cause said at least one computing device to:

generate a plot comprising a plurality of points of right ascensions and declinations to which a boresight of said star tracker points;

determine whether a plurality of tracked stars within said field of view of said star tracker corresponds to a minimum number of star entries in said star catalog at each point of said plurality of points;

code said each point based upon a determination of whether said minimum number of star entries in said star catalog corresponds to said plurality of tracked stars;

generate a visual representation of said dry spot based upon said coding of said each point; and

generate a visual representation of a trajectory of said boresight.

17. The system of claim **15** wherein said instructions, when executed by said at least one computing device, further cause said at least one computing device to determine at least one of:

a location of said occurrence of said dry spot;

a date of said occurrence of said dry spot; and

a duration of said occurrence of said dry spot.

18. The system of claim **15** wherein said instructions, when executed by said at least one computing device, further cause said at least one computing device to:

generate a set of modifications to modify said star catalog;

generate a modification schedule for modifying said star catalog; and

upload said set of modifications to said star catalog.

19. The system of claim **15** wherein said instructions, when executed by said at least one computing device, further cause said at least one computing device to:

determine said plurality of attitudes of a vehicle;

determine a plurality of tracked stars within said field of view of said star tracker at said plurality of attitudes;

determine whether said plurality of tracked stars corresponds to a minimum number of star entries;

determine a tracked star of said plurality of tracked stars that does not correspond to a star entry of said plurality of star entries;

determine a modification star entry corresponding to said tracked star;

determine whether said modification star entry can modify said star catalog; and

include said modification star entry to said set of modifications.

20. The system of claim **19** wherein said instructions, when executed by said at least one computing device, further cause said at least one computing device to:

determine whether said modification star entry comprises an exclusionary property;

determine whether at least one star entry of said plurality of star entries is replaceable;

determine whether said modification star entry is a viable modification to said star catalog; and

recommend said modification star entry when said modification star entry does not comprise said exclusionary property, said star entry is replaceable, and said modification star entry is said viable modification.

21. The system of claim **15** wherein said instructions, when executed by said at least one computing device, further cause said at least one computing device to:

determine said plurality of attitudes of a vehicle;

determine a plurality of tracked stars within said field of view of said star tracker at said plurality of attitudes;

determine a first attitude of said plurality of attitudes where said plurality of tracked stars does not correspond to a minimum number of star entries;

determine a second attitude of said plurality of attitudes where said plurality of tracked stars does correspond to said minimum number of star entries, said second attitude occurring after said first attitude;

determine a location of said occurrence of said dry spot based on said plurality of attitudes where said minimum number of star entries does not correspond to said plurality of tracked stars;

determine a date of occurrence of said dry spot based on a first time coordinate of said first attitude; and

determine a duration of said occurrence of said dry spot based on a time period between a first time coordinate of said first attitude and a second time coordinate of said second attitude.

22. The system of claim **15** wherein said instructions, when executed by said at least one computing device, further cause said at least one computing device to:

determine a first time coordinate where a plurality of tracked stars does not correspond to a minimum number of star entries;

determine a second time coordinate prior to said first time coordinate;

determine whether said second time coordinate meets modification constraints; and

recommend said second time coordinate as a date/time to upload said set of modifications to said star catalog when said second time coordinate meets said modification constraints.

23. The system of claim **15** further comprising:

first magnitude values of a first plurality of stars; and

second magnitude values of a second plurality of stars, said second plurality of stars being a sub-set of said first plurality of stars,

wherein said instructions, when executed by said at least one computing device, further cause said at least one computing device to:

convert said first magnitude values of said first plurality of stars to said second magnitude values of said first plurality of stars; and

predict a plurality of tracked stars within a field of view of a star tracker based on said second magnitude values.

24. The system of claim **15** further comprising:

first attitude data comprising a plurality of first time coordinates and an associated plurality of first attitudes; and

a regular time duration,

wherein said instructions, when executed by said at least one computing device, further cause said at least one computing device to:

generate second attitude data comprising a plurality of second time coordinates and an associate plurality of second attitudes, said plurality of second time coordinates being spaced apart by said regular time duration.

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